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Bethesda, Maryland 20084

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SMP84: IMPROVEMENTS TO CAPABILITY AND PREDICTION ACCURACY OF THE STANDARD SHIP MOTION PROGRAM SMP81

by

William G. Meyers

and

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September 1985

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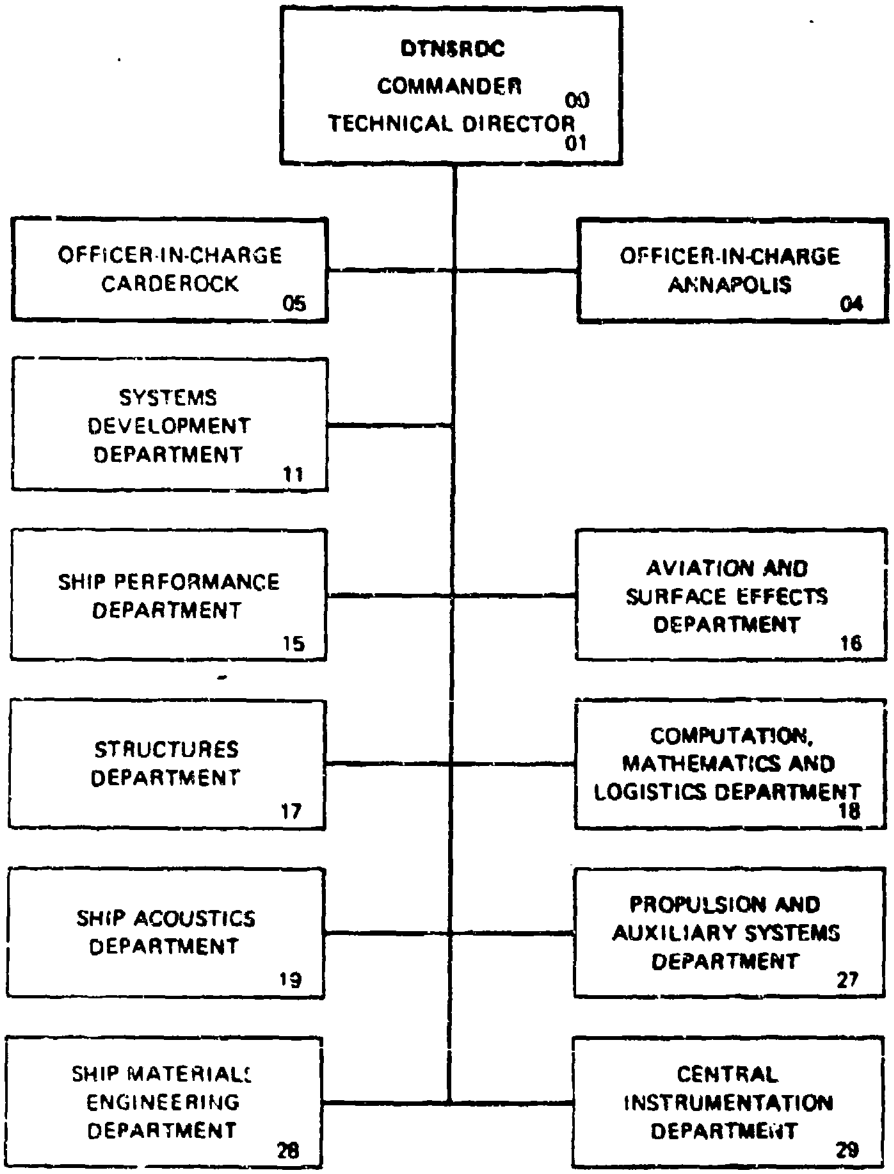

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The Standard Ship Motion Program, SMP, was developed at the David Taylor Naval Ship Research and Development Center in 1981 as a prediction tool for use in the Navy's ship design process. SMP provides predictions of the responses of a ship advancing at constant forward speed with arbitrary heading in both regular waves and irregular seas. Since 1981 a number of corrections and improvements were made to SMP which are detailed in this report.

Corrections were made in the bilge keel viscous damping calculation for ships that have both a bilge keel and a skeg described on the same station. An improvement in yaw-roll coupling was made by using a different theory to compute hull lift damping. New predictions were incorporated into SMP to compute stabilized ship responses for active antiroll fins using fixed gains. Predictions of vertical wave induced loads were also incorporated into SMP. In addition, a new set of tables of severe ship responses is provided as part of the output. Keywords: Computer program documentation; Tables (data); Computer files

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NOTATION

A_{bk}	Bilge keel area
AP	Aft perpendicular
A_p	Appendage added mass term
$\vec{a}$	Unit vector in axial direction of fin
a_e	Aspect ratio of an appendage
a_1, a_2, a_3	Fin servo coefficients
a_{33}	Two-dimensional heave sectional added mass
BL	Baseline of ship
b_j	Load amplitude for j'th mode
b_1, b_2, b_3	Fin controller compensation coefficients
b_{33}	Two-dimensional heave sectional damping
c	Mean chord of an appendage
COFFIL	Base ship coefficient file (TAPE3)
D_j	Hydrodynamic force due to body motion for j'th mode
E_j	Exciting force for j'th mode
e_{bk}	Fin/bilge keel correction factor
e_{bl}	Hull boundary layer correction for fins
$\vec{F}$	Force vector developed by active motion of fin
F^*	Magnitude of force due to active motion of fin
F_{ML}	Magnus lift term
FP	Forward perpendicular
F_y	Component of sway force due to active motion of fin
F_z	Speed dependent unit sway lift force
f_j	Sectional Froude-Kriloff force
f_o	Speed independent unit sway lift force

$\overline{GM}$	Transverse metacentric height
G_V	Speed-dependent fin gain factor
g	Acceleration due to gravity
h_j	Sectional diffraction force
I_j	Inertial force for j'th mode
$\vec{i},\vec{j},\vec{k}$	Direction vectors in x, y, and z directions
K_1,K_2,K_3	Fin controller coefficients proportional to roll angle, roll velocity, and roll acceleration
k	Wave number
LCG	Longitudinal center of gravity referenced from the forward perpedicular
LCOFIL	File (TAPE4) containing section added mass, damping, and exciting forces used in the vertical load calculations
LRAFIL	Load (vertical shear force and vertical bending moment) response amplitude operator file (TAPE10)
L_{cs}	Free stream lift curve slope
$(L_{cs})_E$	Effective lift curve slope
$\vec{M}$	Moment vector developed by active motion of fin
M_ϕ	Component of roll moment due to active motion of fin
M_ψ	Component of yaw moment due to active motion of fin
m	Sectional mass per unit length
$\vec{n}$	Unit vector normal to fin
ORGFIL	Origin motion (surge, sway, heave, roll, pitch, and yaw) transfer function file (TAPE11)
RAO	Response amplitude operator
RMS	Root mean square (square root of variance)
RMSFIL	Root mean square/encountered modal period file (TAPE 13)
ROLLRFT	Computer program used in Canada to compute sway, roll, and yaw in irregular seas

RSV	Response statistical value
R_e	Reynolds number
R_j	Restoring force for j'th mode
r	Radius of rotating fin cylinder
s	Span of an appendage
SEVFIL	File (TAPE14) containing response statistical values/ encountered modal periods for specific responses used in Severe Motion Tables
SMP	Navy standard ship motion program
SMSL	Ship motion and sea load computer program
SMP81	SMP program (1981 version)
SMP84	SMP program (1984 updated version)
SPLFIL	Multiply defined (scratch, ship offsets, response statistical values) file (TAPE15)
STATIS	Rayleigh constant used in computation of response statistical values
T	Draft of ship
TAPE3	File number associated with COFFIL
TAPE4	File number associated with LCOFIL
TAPE10	File number associated with LRAFIL
TAPE11	File number associated with ORGFIL
TAPE13	File number associated with RMSFIL
TAPE14	File number associated with SEVFIL
TAPE15	File number associated with SPLFIL
T_O	Modal wave period
T_{OE}	Response encountered modal period
t	Time variable
V	Ship speed

V_{cg}	Vertical location of center of gravity of ship referenced to the waterplane
V_j	Vertical wave induced load for j'th mode
V_t	Tangential velocity at fin trailing edge
WL	Waterline of ship
X_a	Complex fin servo coefficient
X_b	Complex fin controller compensation coefficient
X_k	Complex fin controller coefficient
x_{cg}	x-coordinate of center of gravity of ship referenced from the forward perpendicular
x_{cp}, y_{cp}, z_{cp}	x, y, z-coordinates of the center of pressure of lifting surfaces
x_{FP}	Distance between the ship forward perpendicular and the longitudinal location of the center of pressure of the fin
x_s	Longitudinal location of the fin shaft
x^*	Location where vertical loads are computed
$\hat{y}$	Distance from vertical center of gravity to center of pressure of a lifting surface
β	Fin angle
β_{LIM}	Fin limit angle
β_{RMS}	Root mean square fin angle
$\beta_{RMS_{LIM}}$	Root mean square fin angle limit
δ	Hull boundary layer thickness
δ_A	Wave amplitude
δ_j	Load phase angle for j'th mode
Γ	Angle that the fin makes to the horizontal
Λ	Sweep angle of fin quarter chord
μ	Ship heading angle
ν	Kinematic viscosity

ξ_j	Six degree of freedom ship motions (surge, sway, heave, roll, pitch, and yaw)
ρ	Mass density of water
ω	Wave frequency in radians per second
ω_E	Encountered wave frequency
⊗	Midlength between perpendiculars, midships

ABSTRACT

The Standard Ship Motion Program, SMP, was developed at the David Taylor Naval Ship Research and Development Center in 1981 as a prediction tool for use in the Navy's ship design process. SMP provides predictions of th responses of a ship advancing at constant forward speed with arbitrary heading in both regular waves and irregular seas. Since 1981 a number of corrections and improvements were made to SMP which are detailed in this report.

Corrections were made in the bilge keel viscous damping calculation for ships that have both a bilge keel and a skeg described on the same station. An improvement in yaw-roll coupling was made by using a different theory to compute hull lift damping. New predictions were incorporated into SMP to compute stabilized ship responses for active antiroll fins using fixed gains. Predictions of vertical wave induced loads were also incorporated into SMP. In addition, a new set of tables of severe ship responses is provided as part of the output.

ADMINISTRATIVE INFORMATION

The David W. Taylor Naval Ship Research and Development Center (DTNSRDC) was authorized and funded over a number of years to develop and improve the capability and accuracy of a standard Navy ship motion prediction computer program and other associated computer programs. This report documents computer program changes and additions to the report DTNSRDC/SPD-0936-01 entitled "User's Manual for the Standard Ship Motion Program, SMP" known as SMP81. Funding was provided by the Surface Ship Hydromechanics Program under Project Element 62543N, Block SF-43-421-001, identified as Work Unit Numbers 1506-103 and 1506-153. Funding was also provided for wave induced vertical loads by Work Request N0002483WR14526, identified as Work Unit Number 1522-950.

INTRODUCTION

The Standard Ship Motion Program, SMP,[1*] was developed at the David Taylor Naval Ship Research and Development Center (DTNSRDC) in 1981 to provide a standard ship motion prediction tool for use in the Navy's ship design process. This program, also known as SMP81, provides predictions in irregular seas of the six degree of freedom ship responses (surge, sway, heave, roll, pitch, and yaw) as well

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*A complete listing of references is given on page 27.

as of the longitudinal, lateral, and vertical responses at specified locations on the ship. Since 1981 a number of corrections and improvements were made to SMP which are detailed in this report.

The modifications to SMP, known collectively as 1984 UPDATES, include:

1. A correction to bilge keel roll damping for ships that have both a bilge keel and a skeg on the same station.

2. An improvement in the roll prediction using a different theory to compute hull lift coefficients.

3. A new theory to compute stabilized ship responses using active antiroll fins with fixed gains.

4. A new prediction of vertical shear force and vertical bending moment at specified cross sections on the ship.

5. The lowest frequency of encounter computed in SMP is now restricted to 0.05 radians per second to avoid calculations of added mass, damping, excitations, and motions at near zero radians per second.

6. A new set of Severe Motion Tables for selected responses is provided as part of the output.

It should be noted that no major alterations were made to SMP in either input, output, files, or the manner in which the program is executed. The updated version of SMP, known as SMP84, will accept input decks prepared for SMP81 as well as files previously generated by SMP81 using these decks. There are changes, however, to both the input deck and some of the files when new features such as active fins and/or vertical loads are selected.

The specific changes to input, output, and files associated with active fins, vertical loads, and severe motion tables are described in separate sections of this report.

A description is provided of the method used to make the program modifications to SMP. The files associated with these program changes are stored on a disk pack on the Control Data Corporation CYBER 176 at DTNSRDC. The last section of this report describes these files and details the procedure used to retrieve the SMP84 file. A listing of the SMP84 source code UPDATES is provided in Appendix A.

This report only describes the changes made to SMP81. It is thus meant to be used as a supplement, not a replacement, for the SMP User's Manual.[1] In addition, the user is referred to Cox and Lloyd[2] for more details concerning the design basis for using active antiroll fins in roll motion stabilization.

SHIP PARTICULARS

Four ships are used for illustrative purposes, these are:

1. USCG 210-ft Medium Endurance Cutter (WMEC) - bilge keel/skeg damping correction
2. DE-1006 - modification to hull lift terms
3. USCG 270-ft Medium Endurance Cutter (WMEC) - active antiroll fins
4. DDG-51 - vertical loads

A listing of the hydrostatic characteristics of each ship is presented in Table 1 and Figure 1 contains the computer-drawn underwater hull shapes.

UPDATES TO THEORY

It is assumed in this report that the user is already familiar with the ship motion theory, variables, coordinate system, files, and input/output schemes that are described in the SMP User's Manual.[1] These details will not be repeated here. Only the changes made to SMP81 are described below.

BILGE KEEL/SKEG DAMPING CORRECTION

Most of the problems that users have experienced in running SMP involve the proper selection of input. Spline routines are used extensively to fit the hull. These spline fits are sensitive to curves with sharp corners or that have uneven point spacing (some points too close together and other points spaced too far apart). This type of problem is corrected by using a different point selection and thus did not require a programming change.

A different problem occurred in the calculation of bilge keel viscous roll damping for ships that have both a skeg and a bilge keel on the same station. A variable called the "radius of the bilge" shown in Figure 2 was incorrectly computed near the centerline of the ship instead of near the bilge keel, due to the presence of the skeg. This error caused a significant increase in bilge keel damping even though the skeg may have only overlapped part of the bilge keel.

This error has been corrected in SMP84. An example illustrating the change in the bilge keel component of roll damping is shown in Figure 3 for a 210-foot United States Coast Guard cutter. A comparison of total damping between the SMP81 and SMP84 predictions as well as measured damping from full-scale trials is also shown in Figure 3.

The SMP84 total damping prediction for this ship reflects an additional decrease in roll damping due to a change in the method of computing hull lift which is discussed in the next section.

MODIFICATIONS TO HULL LIFT TERMS

One of the improvements made to SMP in 1981 was the incorporation of hull and appendage lift terms in the lateral equations of motion. Validation runs[3] of SMP were made in 1981 for the DE-1006 which showed a definite improvement in the prediction of the roll transfer functions at high speed. Although the magnitudes of the peak values were predicted quite well, there was a general tendency to shift the roll transfer functions to longer wavelengths than showed by experiment.

Subsequent checks of these validation runs were made for the DE-1006 at the lowest $\overline{GM}$ value, GM3, at zero-speed and at 27 knots in beam waves. A discrepancy was found between the zero-speed undamped natural roll period, T_ϕ, computed in SMP and the measured roll period shown in Figure 4 (taken from Reference 3) for the GM3, BK4 (no bilge keel) condition.

The undamped roll period was computed in SMP from the natural roll frequency, ω_ϕ, as

$$\omega_\phi^2 = \Delta\, \overline{GM}/(I_{44} + A_{44}) \tag{1}$$

$$T_\phi = 2\pi/\omega_\phi \tag{2}$$

where Δ is the ship displacement, $\overline{GM}$ is the metacentric height, I_{44} is the structural moment of inertia, and A_{44} is the hydrodynamic moment of inertia. Here I_{44} is computed as

$$I_{44} = M\, K_\phi^2 \tag{3}$$

where M is the mass of the ship and K_ϕ is the roll radius of gyration.

The measured value of K_ϕ provided as input to SMP for the validation runs was 35 percent of the beam. The $\overline{GM}$ value computed in SMP was 6 percent of the

beam which agreed with the measured value of $\overline{GM}$. The roll period computed in SMP for these values of K_ϕ and $\overline{GM}$ was 10 seconds. The measured roll period shown in Figure 4 was 9.3 seconds. This discrepancy in period was resolved by assuming that the measured value of K_ϕ already contained a hydrodynamic component as well as a structural component, i.e., the natural roll frequency should have been computed for this ship as

$$\omega_\phi^2 = \Delta\,\overline{GM}/I_{44_T} \tag{4}$$

where

$$I_{44_T} = M\,(K_{\phi MEASURED})^2 \tag{5}$$

The structural radius of gyration, required as input for SMP was then recomputed as

$$(K_{\phi STRUCTURAL})^2 = (K_{\phi MEASURED})^2 - A_{44}/M \tag{6}$$

which gave a value of 32 percent of the beam. The new roll period was then computed by SMP as 9.3 seconds which agreed with the measured roll period at zero knots.

This modification to the radius of gyration corrected part of the shift of the predicted roll transfer functions to longer wavelengths at speed but did not eliminate it.

Similar roll validation runs were made by Schmitke[4] in 1978 for the DE-1006 using a computer program called ROLLRFT which also incorporated terms for hull and appendage lift. These validation runs, made using ROLLRFT, showed a similar good agreement in predicting the peak values of the roll transfer functions at high speed. In addition, the roll transfer functions were predicted quite well at each frequency, i.e., there was no tendency to shift the transfer functions to longer wavelengths as shown in SMP.

A comparison was made of the theories for hull and appendage lift that were implemented in SMP and ROLLRFT. It was determined that the only significant difference in these lift theories was in the theory used to obtain hull lift. A discussion of the differences of the two theories of hull lift as implemented in SMP81 and ROLLRFT is provided next.

The hull is treated in SMP81 as a low aspect ratio lifting surface that generates a sway lift force and a corresponding roll lift moment at the x,y,z location of the center of pressure

$$x_{cp} = 0 \tag{7a}$$

$$y_{cp} = 0 \tag{7b}$$

$$z_{cp} = -(V_{cg} + T/2) \tag{7c}$$

where V_{cg} is the vertical center of gravity of the ship referenced to the waterplane and T is the draft of the ship.

The hull lift terms that are added to the left-hand side of the lateral equations of motion are

$$b_{22L} = F_z \sin^2 \Gamma \tag{8}$$

$$b_{24L} = -F_z \hat{y} \sin \Gamma \tag{9}$$

$$c_{26L} = -V\, b_{22L} \tag{10}$$

$$b_{42L} = b_{24L} \tag{11}$$

$$b_{44L} = F_z \hat{y}^2 \tag{12}$$

$$c_{46L} = -V\, b_{24L} \tag{13}$$

$$c_{62L} = V\, b_{22L} \tag{14}$$

$$c_{64L} = V\, b_{24L} \tag{15}$$

$$b_{66L} = (V^2/\omega_E{}^2)\, b_{22L} \tag{16}$$

where the angle Γ that the hull makes to the horizontal axis is -90 degrees, $\hat{y}$ is the moment arm from the center of gravity to the center of pressure, V is the ship speed, and ω_E is the wave frequency of encounter.

The hull lift corrections to the sway exciting force, roll exciting moment, and yaw exciting moment are determined at the center of pressure as

$$F_{2L} = f_2 \sin\Gamma \tag{17}$$

$$F_{4L} = - f_2 \hat{y} \tag{18}$$

$$F_{6L} = (V/i\omega_E)\, F_{2L} \tag{19}$$

where

$$f_2 = F_z\ \omega \sin\Gamma \sin\mu \exp(k\, z_{cp}) \tag{20}$$

Here ω is the wave frequency and k is the wave number. The unit sway lift force, F_z, is

$$F_z = (\rho/2)\, A\, V\, L_{cs} \tag{21}$$

where ρ is the mass density of water, A is the area (span x mean chord) and L_{cs} is the lift curve slope.

The hull is also treated as a low aspect ratio lifting surface in the Schmitke ROLLRFT program which uses the theory of Mandel[5]. This theory assumes that a force "couple" is generated by the hull at speed with no net sway lift force or roll lift moment. A yaw moment is developed, however, due to the force couple.

x_{cp} is computed at the centroid of area of the hull as

$$x_{cp} = \frac{\int \eta T_\eta \, d\eta}{\int T_\eta \, d\eta} \tag{22}$$

where T_η is the sectional draft. y_{cp} and z_{cp} are assumed to be zero. The moment arm used for the force couple is computed as

$$C_p\, L_{pp}/2$$

where C_p is the prismatic coefficient and L_{pp} is the length between perpendiculars.

The ROLLRFT hull lift terms added to the left-hand side of the lateral equations are

$$b_{22L} = F_z \sin^2 \Gamma \tag{23}$$

$$b_{26} = x_{cp}\, b_{22L} \tag{24}$$

$$c_{26} = -V\, b_{22L} \tag{25}$$

$$b_{62L} = x_{cp}\, b_{22L} \tag{26}$$

$$c_{62L} = V\, b_{22L} \tag{27}$$

$$b_{66L} = (C_p\, L_{pp}/2)^2\, b_{22L} + (V^2/\omega_E{}^2)\, b_{22L} \tag{28}$$

The additions to the sway exciting force and the yaw exciting moment due to hull lift are assumed by Schmitke[4] to be distributed along the length of the ship as

$$F_{2L} = \frac{\int T_\eta \sin\Gamma\, f_{2L_\eta}\, d\eta}{\int T_\eta\, d\eta} \tag{29}$$

$$F_{6L} = \frac{\int [\eta + (V/i\omega E)]\, T_\eta \sin\Gamma\, f_{2L_\eta}\, d\eta}{\int T_\eta\, d\eta} \tag{30}$$

where

$$f_{2L_\eta} = F_z\; \omega \sin\Gamma \cos\mu \exp\, [k(T/2) - i\eta \cos\mu] \tag{31}$$

The hull lift theory of Mandel[5] as implemented by Schmitke[4] in ROLLRFT was incorporated into SMP84. New validation runs for the DE-1006 were made using SMP84 and an improvement was found in the prediction of the roll transfer function at high speed. The SMP84 predictions agreed reasonably well with experiment and with Schmitke's predictions for the DE-1006. A comparison of the SMP84 roll transfer function predictions with experiment and with the SMP81 predictions is

shown in Figure 5 for the DE-1006 in beam waves at 0 and 27 knots for the GM3, BK1 condition. It should be noted that the SMP81 and SMP84 transfer function comparisons are identical at 0 knots.

ACTIVE ANTIROLL FINS

Appendages are input into SMP in order to compute their contributions to roll damping due to lift. These appendages include fins, rudders, skegs, and propeller shaft brackets. The appendages used in SMP are considered to be passive. One of the improvements made to SMP was the incorporation of active antiroll fins in the lateral equations of motion. The active fins use fixed gains which vary with speed. The gains as well as controller characteristics are provided as input to SMP by the user. A method for determining these gains is discussed later in this section.

The force, $\vec{F}$, and moment, $\vec{M}$, developed by the active motion of a fin are

$$\vec{F} = \vec{n}\ \{-A_p(x_{cp} - x_s)\ddot{\beta} + [3\ A_p V - f_o V(x_{cp} - x_s)]\ \dot{\beta} + f_o V^2 \beta\}$$

$$= \vec{n} F^* \tag{32}$$

$$\vec{M} = \vec{r}_{cp} \times \vec{F}$$

$$= \vec{r}_{cp} \times \vec{n} F^* \tag{33}$$

where F^* is the magnitude of the force due to the active fin motion, β. The dots used in Equation (32) stand for time derivatives so that $\dot{\beta}$ and $\ddot{\beta}$ are fin rate and fin acceleration respectively.

The variable V in Equation (32) is the ship speed and x_s is the longitudinal location of the fin shaft referenced to the longitudinal location of the center of gravity of the ship. The longitudinal location of the center of pressure of the fin, x_{cp}, is assumed to be at the fin shaft for a passive fin but to move aft of the fin shaft for an active fin. The longitudinal distance, $x_{cp} - x_s$, is assumed to be 1/6th of the mean chord for an active fin.

The fin added mass term, A_p, is defined as

$$A_p = \pi\rho\, s(\bar{c}/2)^2 \tag{34}$$

where ρ is the mass density of water, s is the span, and $\bar{c}$ is the mean chord. The term f_o is defined as

$$f_o = (\rho/2)\, A\, L_{cs} \tag{35}$$

where A is the planform area of the fin, and L_{cs} is the fin lift curve slope. The position vector, $\vec{r}_{cp}$, is defined as

$$\vec{r}_{cp} = \vec{i}x_{cp} + \vec{j}y_{cp} + \vec{k}z_{cp} \tag{36}$$

where x_{cp}, y_{cp}, and z_{cp} are the locations of the center of pressure of the fin referenced to the vertical center of gravity of the ship.

The vector, $\vec{n}$, in Equation (32) is the unit vector normal to the fin, defined as

$$\vec{n} = \vec{i}0 - \vec{j}\sin\Gamma + \vec{k}\cos\Gamma \tag{37}$$

where Γ is the angle that the passive fin makes with respect to the horizontal axis. The unit vector, $\vec{n}$, the angle Γ, and the position vector $\vec{r}_{cp}$ are shown in Figure 6.

The fin rate term, $3A_pV\dot{\beta}$, in Equation (32) is known as the Magnus Lift term.[6] This lift term occurs because an active fin behaves in a manner similar to a rotating cylinder in a flow. The general form of the Magnus Lift term is

$$F_{ML} = 2\pi(V_t/V)(2rs)(\rho V^2/2) \tag{38}$$

where the tangential velocity at the trailing edge of the fin, V_t, is

$$V_t = (3\bar{c}/4)\dot{\beta} \tag{39}$$

The radius r of the rotating fin cylinder is

$$r = \bar{c}/2 \tag{40}$$

Substituting V_t and r into Equation (38)

$$\begin{aligned} F_{ML} &= 2\pi(3c/4)\dot{\beta}\,\bar{c}\;s(\rho/2)V \\ &= 3[\pi\rho s(\bar{c}/2)^2]V\dot{\beta} \\ &= 3A_p V\dot{\beta} \end{aligned} \tag{41}$$

The components of sway force, F_y, roll moment, M_ϕ, and yaw moment, M_ψ, are obtained by substituting the expressions for $\vec{r}_{cp}$ and $\vec{n}$ into Equations (32) and (33)

$$F_y = -\sin\Gamma\; F^* \tag{42}$$

$$M_\phi = \hat{y}\; F^* \tag{43}$$

$$M_\psi = -x_{cp}\;\sin\Gamma\; F^* \tag{44}$$

where

$$\hat{y} = y_{cp}\cos\Gamma + z_{cp}\sin\Gamma \tag{45}$$

The fin stabilized lateral equations of motion are obtained by adding F_y, M_ϕ, and M_ψ to the left-hand sides of the sway equation, roll equation, and yaw equation, respectively.

The commanded motion of the fin, β, is determined using a control law operating on the roll motion of the ship and its time derivatives as

$$\beta = G_V\;[X_k/(X_a \cdot X_b)]\;\phi \tag{46}$$

where G_V is a speed-dependent gain factor. X_k, X_a, and X_b are complex coefficients defined as

$$X_k = (K_1 - \omega_E^2\,K_3) + i\;\omega_E K_2 \tag{47}$$

$$X_a = (a_1 - \omega_E^2\ a_3) + i\ \omega_E a_2 \quad (48)$$

$$X_b = (b_1 - \omega_E^2\ b_3) + i\ \omega_E b_2 \quad (49)$$

where K_1, K_2, and K_3 are fin controller coefficients proportional to roll acceleration, roll velocity, and roll angle; a_1, a_2, and a_3 are fin servo coefficients; and b_1, b_2, and b_3 are fin controller compensation coefficients.

The coefficients G_V and K_j, a_j, and b_j, where j=1 to 3, are required as input in SMP. Nominal values for these coefficients were obtained from Reference 2 and are shown in Table 2.

The free-stream fin lift curve slope in Equation (35) is computed in SMP as

$$L_{cs} = 1.8\ \pi\ a_e/[\cos\ \Lambda(a_e^2\ \sec^2\ \Lambda + 4)^{1/2} + 1.8] \quad \text{per radian} \quad (50)$$

where a_e is the effective aspect ratio of the fin, i.e., 2s/c and Λ is the sweep angle of the fin quarter chord.

The user can optionally input an effective lift curve slope which takes into account fin performance degradation due to the effects of hull boundary layer, fin/bilge keel, and fin/fin interference effects. The user is referred to Reference 2 for methods that can be used to determine these degradation effects. One degradation effect discussed in Reference 2 that should not be used involves fin-induced sway and yaw motions. Reference 2 used this particular effect to account for sway and yaw motions in a one degree-of-freedom roll equation to compute stabilized roll for active fins. SMP does not require this degradation effect because it uses a three degree-of-freedom math model to compute stabilized sway, roll, and yaw directly using the fin sway force, fin roll moment, and fin yaw moment from Equations (42), (43), and (44).

Finally, if the user does not have specific values for the fin gain factors G_V, it will be necessary to find them iteratively by making a number of runs of SMP for a range of G_V values using program option OPTN=3 and OPTN=5 in Data Card Set 2. The user is referred to Reference 1 for the details of running SMP.

The procedure involves applying a specific fin angle limit criteria, based on occurrence of fin stock strength, stall, cavitation, and/or reduced noise considerations (see Reference 2), to the root mean square fin angles output by SMP at the

heading which produces the worst roll motion in a design seaway. It should be noted that the significant wave height for this design seaway should be input by the user in Data Card Set 14. A root mean square statistic, STATIS=1.00, should also be input in Data Card Set 14 when making the iterative runs of SMP.

Typically, the user selects a fin limit angle, β_{LIM}, (e.g., 21 degrees at 15 knots) for each speed with a one in ten probability of being exceeded. This means that for a particular speed, the root mean square fin angle, β_{RMS}, is determined as

$$\beta_{RMS} = \beta_{LIM}/2.146 \qquad (51)$$

where 2.146 is the Rayleigh constant used to compute this probability of exceedance.

Next, the user plots the fin angle RMS values at the worst roll heading in the design seaway as a function of the G values that were used in the various runs of SMP. The fin RMS limit criteria, β_{RMS}, for each speed are then plotted. The appropriate value of G_V for each speed can then be determined from the intersection of β_{RMS} at that speed and the curve of computed RMS fin angle as a function of G. An example of this type of plot is shown in Figure 7 for a 270-foot United States Coast Guard cutter.

VERTICAL LOADS

The theory of Salvesen, Tuck, and Faltinsen[7] is use to compute the vertical wave-induced loads at specified cross sections of a ship advancing at constant forward speed with arbitrary heading in regular sinusoidal waves. These loads are expressed for a given ship speed, heading angle, and frequency of encounter, ω_E, as:

$$V_j = b_j \cos(\omega_E t + \delta_j) \qquad (52)$$

where b_j is the load amplitude with $j=3$ referring to the vertical shear force and $j=5$ referring to the vertical bending moment. The phase angles δ_j refer to the phase lead of j^{th} load with respect to the maximum wave elevation at the origin of the x,y,z coordinate system shown in Figure 8. This right-handed coordinate system is moving with the constant mean forward speed of the ship with the origin lying in the undisturbed free surface and located at the longitudinal center of

gravity. The coordinate system is defined with z positive vertically upward through the center of gravity of the ship, y positive to port, and x positive in the direction of forward motion of the ship.

The sign convention of the vertical loads is also shown in Figure 8. The loads are located at the specified cross section with the vertical shear force, V_3, positive upward and the vertical bending moment, V_5, positive bow down. It should be noted that V_5 is actually the moment about the horizontal axis. It is referred to as the vertical bending moment by convention since it is the moment due to the vertical forces.

The vertical shear force is computed as the difference between the inertia force and the sum of the external forces acting on the portion of the hull forward of the specified cross section:

$$V_3 = I_3 - (R_3 + E_3 + D_3) \tag{53}$$

where I_3 is the inertial force, R_3 is the static restoring, E_3 is the exciting force, and D_3 is the hydrodynamic force due to the body motion. Similarly, the vertical bending moment is computed as the difference of the moment due to the inertia force and the sum of the moments due to the external forces:

$$V_5 = I_5 - (R_5 + E_5 + D_5) \tag{54}$$

The vertical inertia force is equal to the mass times the acceleration:

$$I_3 = \int m\ (\ddot{\xi}_3 - \eta\ddot{\xi}_5)\ d\eta \tag{55}$$

where m is the sectional mass per unit length, $\ddot{\xi}_3$ is the heave acceleration, and $\ddot{\xi}_5$ is the pitch acceleration. The sign convention of the six degree of freedom motions, ξ_j, are shown in Figure 8. The integration is over the portion of the ship forward of the specified cross section.

The vertical moment of inertia is defined as:

$$I_5 = -\int m\ (\eta - x^*)\ (\ddot{\xi}_3 - \eta\ddot{\xi}_5)\ d\eta \tag{56}$$

where x^* is the longitudinal location of the cross section referenced to the origin of the x,y,z coordinate system in Figure 8.

The vertical hydrostatic restoring force and moment over the portion of the ship forward of the cross-section at x^* are given by:

$$R_3 = -\rho g \int b\ (\xi_3 - \eta\xi_5)\ d\eta \tag{57}$$

$$R_5 = \rho g \int b\ (\eta - x^*)\ (\xi_3 - \eta\xi_5)\ d\eta \tag{58}$$

where ρ is the mass density of water, g is the acceleration of gravity, and b is the sectional beam.

The exciting force and moment over the portion of the ship forward of the cross section at x^* are defined as:

$$E_3 = \rho\zeta_A\ \{\int (f_3 + h_3) d\eta + [(V/i\omega_E)\ h_3)]_{\eta = x^*}\}\ \exp(i\omega_E t) \tag{59}$$

$$E_5 = -\rho\zeta_A \int [(\eta - x^*)\ (f_3 + h_3) + (V/i\omega_E) h_3] d\eta\ \exp(i\omega_E t) \tag{60}$$

where ζ_A is the wave amplitude and V is the ship speed.

The sectional Froude-Kriloff "force" is given by:

$$f_3 = g\ \exp(-ik\eta\cos\mu) \int_{C_\eta} N_3\ \exp(iky\sin\mu)\ \exp(kz) dl \tag{61}$$

and the sectional diffraction force is given by:

$$h_3 = \omega\ \exp(-ik\eta\cos\mu) \int_{C_\eta} (iN_3 - N_2\sin\mu)\ \exp(iky\sin\mu)\ \exp(kZ)\ \phi_3\ dl \tag{62}$$

Here k is the wave number and μ is the ship heading angle relative to the incident wave. N_2 and N_3 are the two-dimensional sectional normal components. C_η denotes the cross-section at longitudinal location η.

The hydrodynamic force and moment due to the body motion on the portion of the ship forward of the cross section at x^* are given by:

$$D_3 = -\int \{a_{33}(\ddot{\xi}_3 - \eta\ddot{\xi}_5) + b_{33}(\ddot{\xi}_3 - \eta\ddot{\xi}_5)$$

$$- (V/\omega_E{}^2) b_{33}\ddot{\xi}_5 + V a_{33}\dot{\xi}_5\} \, d\eta$$

$$- [V a_{33} \, (\dot{\xi}_3 - \eta\dot{\xi}_5) - (V/\omega_E{}^2) b_{33}(\ddot{\xi}_3 - \eta\ddot{\xi}_5)$$

$$- (V^2/\omega_E{}^2)(a_{33}\ddot{\xi}_5 + b_{33}\dot{\xi}_5)]_{\eta=x^*} \qquad (63)$$

and,

$$D_5 = \int (\eta - x^*) \{a_{33}(\ddot{\xi}_3 - \eta\ddot{\xi}_5) + b_{33}(\dot{\xi}_3 - \eta\dot{\xi}_5)\} \, d\eta$$

$$+ \int \{V a_{33}(\dot{\xi}_3 - x^*\dot{\xi}_5) - (V/\omega_E{}^2)(\ddot{\xi}_3 - x^*\ddot{\xi}_5)$$

$$- (V^2/\omega_E{}^2)(a_{33}\ddot{\xi}_5 + b_{33}\dot{\xi}_5)\} \, d\eta \qquad (64)$$

where a_{33} and b_{33} are the two-dimensional sectional added-mass and damping for heave.

RESTRICTION ON ENCOUNTER FREQUENCY CALCULATION

The frequency of encounter, ω_E, is computed as

$$\omega_E = |\omega - (\omega^2 V/g)\cos\mu| \qquad (65)$$

where V is the mean forward speed of the ship, μ is the heading angle, and ω is the wave frequency.

The two-dimensional velocity potentials as well as the zero speed added mass and damping coefficients are calculated in SMP over a fixed range of 10 encounter frequencies from 0.05 to 10.0 radians per second. The 2-D velocity potentials and added mass and damping coefficients are then spline fitted over this range of 10 encounter frequencies. The 2-D velocity potentials and added mass and damping for specific ω_E values, computed in Equation (65) for various ship speeds, headings and wave frequencies, are then obtained by interpolation from the spline fitted potentials and zero speed added mass and damping coefficients.

The spline interpolation routines in SMP do not allow extrapolation outside the range of the independent variable, i.e., the range of encounter frequencies from 0.05 to 10.0 radians per second. However, it was found that at high speed in

quartering/following waves that ω_E values near zero radians per second were computed using Equation (65) and that the 2-D potentials and added mass and damping coefficients were being extrapolated to these near zero encounter frequencies. The extrapolation was done because other source coding was used for interpolation instead of the spline interpolation routines. This resulted in very large unrealistic values for the wave excitations on the right hand side in the equations of motion for these near zero encounter frequencies.

The ω_E values computed using Equation (65) in SMP84 are set to 0.05 if they are less than 0.05 radians per second. In addition, a separate range of 100 encounter frequencies used in SMP to interpolate encounter spectra was modified so that the lowest encounter frequency would be 0.05. The modified set of encounter frequencies is now 0.05 (0.01) 0.58, 0.60 (0.02) 1, 1.1 (0.1) 2, 2.2 (0.2) 4, 4.4 (0.4) 6. The variable frequency increment is shown in the parenthesis.

SMP PROGRAM CHANGES

INPUT

The input for SMP consists of hull form data, loading data, appendage data, point location data, and environment data. This input is broken down into 15 Data Card Sets which are described in Appendix C of Reference 1. The modifications to SMP to incorporate vertical loads required changes to Data Card Set 2 (Program Options) and Data Card Set 6 (Underwater Hull Geometry). Modifications for active antiroll fins required changes to Data Card Set 11 (Fin). The changes to these three data card sets are described below:

Data Card Set 2, Program Options

A new printing option (LRAOPR, integer, column 25) is provided to print out the vertical shear force and vertical bending moment response amplitude operators (RAO) and phase angles. A new load RAO file (TAPE10) is generated only when the LRAOPR option is selected. The values of LRAOPR are

0 or blank - No load RAO printout.

1 - Print out the load RAO's and generate a load RAO file when OPTN=2 through 6. OPTN is the major program option specified in column 5 of this data card set. A load coefficient file (TAPE4) must be attached when OPTN=4 through 6. An origin file (TAPE11) must also be attached when OPTN=6.

In addition, the load variable NLOADS, must be selected in Data Card Set 6 to obtain the load RAO printout.

Data Card Set 6, Underwater Hull Geometry

A new option (NLOADS, integer, columns 9-10) is provided on the first card of this data card set. NLOADS specifies the number of stations (maximum of 10) where vertical loads are to be computed. No vertical loads are computed when NLOADS is specified as either 0 or blank. If the load option is selected (NLOADS > 0), two additional sets of information must be provided at the end of this data card set after the stations and hull offsets or Lewis forms have been input.

First, the station weight (SWGHT, real array, 8F10.4) is input for each of the stations specified previously in this data card set. The weight units are metric tons (mass unit) if PUNITS="METER" or long tons (weight unit) if PUNITS="FEET". The variable PUNITS is specified in Data Card Set 3. The weight curve for the DDG-51 is shown in Figure 9.

Second, the stations (XLDSTN, real array, 8F10.4) where loads are to be calculated are input. The variable NLOADS determines the number of load stations that are specified. A load station must correspond exactly to one of the station numbers specified earlier in this data card set.

Data Card Set 11, Fin

Two new variables associated with active fins are provided on the first card of this data card set. The first variable (IACTFN, integer, column 10) specifies whether the fins are active (IACTFN=1) or passive (IACTFN=0). The second variable (IFCLCS, integer, column 15) allows the user (IFCLCS=1) to input an effective lift curve slope for each speed and fin.

Four new cards, denoted as cards 1.1, 1.2, 1.3, and 1.4, must be input after the first card when active fins are selected. These cards are skipped when IACTFN=0.

Card 1.1 - FORMAT (8F10.4)

(1) FGAIN (array), real, columns 1-10, 11-20, . . ., [(NVK-1)*10+1] - [NVK*10], speed-dependent fin gain factors, G_V. NVK is the number of ship speeds.

Card 1.2 - FORMAT (3F10.4)

(1) FK (array), real, columns 1-10, 11-20, 21-30, fin controller coefficients where FK(1) is proportional to roll angle, FK(2) is proportional to roll velocity, and FK(3) is proportional to roll acceleration.

Card 1.3 - FORMAT (3F10.4)

(1) FA (array) real, columns 1-10, 11-20, 21-30, fin servo coefficients

Card 1.4 - FORMAT (3F10.4)

(1) FB (array), real, columns 1-10, 11-20, and 21-30, fin controller compensation coefficients.

Nominal values for FK, FA, and FB, taken from Reference 2, are shown in Table 2. FGAIN is either known for existing ships or determined by making iterative runs of SMP following the procedure described in the active fin section of this reqport.

The next card, denoted as 1.5, is required for each fin set if the user wants to input (IFCLCS=1) and effective lift curve slope. Card 1.5 follows Card 1.4 when IACTFN=1 or Card 1 when IACTFN=0. Card 1.5 is skipped when IFCLCS=0.

Card 1.5 - FORMAT (8F10.4)

(1) FCLCS, array, real, columns 1-10, 11-20, . . ., [(NVK-1)*10+1] - [NVK*10], speed-dependent effective fin lift curve slope, L_{cs}, for a particular fin set. The user is referred to Reference 2 as well as the section on active fins for methods than can be used to determine L_{cs}.

Note that Card 1.5 is input consecutively for each fin set prior to inputting Card 2, which provides the geometric description of the fins.

OUTPUT

The basic format of the SMP output remains unchanged in SMP84. However, the following sections were modified to provide output for active antiroll fins and/or vertical loads:

1. Input Card Description for fins and loads.
2. Response Amplitude Operators for loads.
3. Response Statistical Value (RSV)/Encountered Modal period (T_{OE}) tables for fins and loads.

Two examples are provided to illustrate these output modifications. The first example is for active antiroll fins on a 270-foot United States Coast Guard Cutter. The SMP input deck for this ship is shown in Table 3. Table 4 shows the change

in the input card description for Data Card Set 11 to print out the values of the variables IACTFN, IFCLCS, FGAIN, FK, FA, FB, and FNCLCS. An effective lift curve slope is provided in the speed-dependent input variable FNCLCS to allow for the effect of hull boundary layer as well as the fin performance degradation due to the presence of a bilge keel aft of the fin. The procedure used to compute the effective lift curve slope, taken from Reference 2, is

$$(L_{cs})_E = [e_{bl}(1 - e_{bk})]L_{cs} \tag{66}$$

where L_{cs} is the free stream fin lift curve slope defined in Equation (50). The hull boundary layer correction, e_{bl}, is defined as

$$e_{bl} = 1 - 0.50(\delta/s)/L_{cs} \tag{67}$$

where s is the fin span. The boundary layer thickness, δ, is defined as

$$\delta = 0.377\ x_{FP}(R_e)^{-0.2} \tag{68}$$

where x_{FP} is the distance between the ship forward perpendicular and the longitudinal location of the center of pressure of the fin, $(x_{cp})_{fin}$. The Renolds number, R_e, is

$$R_e = x_{FP}V/\nu \tag{69}$$

where V is the ship speed and ν is the kinematic viscosity.

The bilge keel/fin degradation correction, e_{bk}, is defined as

$$e_{bk} = 0.22\ (a_e)_{bk}\ \{1 + [1 + (s/d_{fb})^2]^{1/2}\}\ (A_{bk}/s^2) \tag{70}$$

where A_{bk} is the area of the bilge keel and d_{fb} is the distance between $(x_{cp})_{fin}$ and the midlength location of the bilge keel, $(x_{cp})_{bk}$. The aspect ratio of the bilge keel, $(a_e)_{bk}$, is defined as

$$(a_e)_{bk} = 2\ s_{bk}/\bar{c}_{bk} \tag{71}$$

where s_{bk} and c_{bk} are the bilge keel span and mean chord respectively.

The kinematic viscosity, ν, is provided as part of the SMP input in Data Card Set 2. The values for A_{bk}, s_{bk}, c_{bk}, s, L_{cs}, $(x_{cp})_{fin}$ and $(x_{cp})_{bk}$ are printed out in the Roll Damping Tables which can be obtained by specifying RLDMPR=1 in Data Card Set 2. The reference for $(x_{cp})_{fin}$ and $(x_{cp})_{bk}$ is the longitudinal center of gravity of the ship, LCG. LCG itself is referenced to the forward perpendicular and is printed out in the Hydrostatic Table.

The values computed for e_{bl}, e_{bk} and $(L_{cs})_E$ for the USCG 270-foot cutter were 0.9684, 0.1352, and 2.118, respectively, at a ship speed of 15 knots. Thus the value used for the input variable FNCLCS at 15 knots was 2.118. The uncorrected free stream value of 2.529 was used for FNCLCS at zero knots.

It is necessary for the user to make an initial run of SMP for the unstabilized ship (fin gain of zero) using the roll motion only option in Data Card Set 2 with RLDMPR=1 in order to obtain the Hydrostatic Table and the Roll Damping Table. The values of FNCLCS can then be computed from information provided in these tables and provided in the SMP input for succeeding SMP runs for active fins.

The values used for FK, FA, and FB are taken from Reference 2. The values for FGAIN were obtained using the iteration procedure described in the section of this report on active fins. A fin limit angle of 21 degrees was applied at a ship speed of 15 knots, heading of 105 degrees (head seas equals 0 degrees), in short-crested seas with significant wave height of 3.96 meters (13 feet) and modal wave period of 9 seconds. The nondimensional roll decay coefficients are shown in Table 5. The short-crested RSV/T_{OE} printout for unstabilized roll angle, stabilized roll angle, stabilized roll velocity, fin angle, and fin velocity are shown in Tables 6 through 10. Note that the significant single amplitude statistic (STATIS=2, Data Card Set 14) was used in this example.

The second example illustrates the vertical load output for the DDG-51. The SMP input deck for this ship is shown in Table 11. Table 12 shows the change in the input card description for Data Card Set 2 to print out the value for LRAOPR. LRAOPR=1 in this example specifies that the Response Amplitude Operators for Vertical Shear Force and Vertical Bending Moment are to be printed out. Table 13 shows the change in the input card description for Data Card Set 6 for loads. The variable NLOADS on the first card of this card set specifies that the vertical loads for one station are to be computed. At the end of this card set, the weight curve in units of long tons is printed out as a function of station. The specific

station, 10.5 in this example, where vertical loads are to be calculated is printed out next after the weight curve.

Table 14 shows the RAO's and phase angles for the Vertical Shear Force, called V.SHEAR(V3) on the printout, and Vertical Bending Moment, called V.MOM.(V5), at a ship speed of 15 knots and a heading angle of 45 degrees. This is the same format used to print out the RAO's and phases for the six degree of freedom motions in SMP.

Table 15 shows the RSV/T_{OE} values for the Vertical Shear Force, called V.SHEAR FORCE in this printout, at station 10.5 in short-crested seas for a significant wave height of 10 feet. The force physical units are in long tons/100. Table 16 shows the RSV/T_{OE} values for the Vertical Bending Moment, called V.BEND. MOMENT, for the same sea condition. The moment physical units are in foot-long tons/10000. The format for these load RSV/T_{OE} values is identical to that used for the other ship responses printed out by SMP.

A new output section which provides tables for severe motions is discussed in the next section of this report.

SEVERE MOTION TABLES

For design purposes it is important to know the worst (maximum) values of the most important ship responses; heave, pitch, sway, roll, yaw, and the vertical and lateral accelerations for up to four locations on the ship specified by the user. The new severe motion tables provide this information in both long-crested and short-crested seas for up to four seaways. Each seaway is defined by a significant wave height input by the user and a most probable wave period determined in SMP. Table 17 shows the most probable periods used in SMP for various ranges of significant wave height given in meters.

Each severe motion table is organized into two parts. The first part provides the maximum Response Statistical Value (RSV) and associated Encountered Modal period (T_{OE}) for each of the responses listed above. The ship speed and heading where these maximum responses occur are also given in this first part. The maximum RSV/T_{OE} values are obtained from the standard response statistical tables that are output by SMP. It should be noted that the statistic used for these tables (RMS, SIGNIFICANT SINGLE AMPLITUDE, etc.) is input by the user.

Another set of information that is useful to know is what the associated responses are at the conditions (speed and heading) where the maximum responses

occur. This information is provided in matrix form in the second part of each severe motion table. Each row of the matrix is associated with one of the maximum responses which is listed at the beginning of the row. The speed and heading where the maximum response occurs is listed next in the row. The RSV-T_{OE} values for all of the responses at this speed and heading are listed next in the row.

An example of the new severe motion table is provided in Table 18 for a 270-foot United States Coast Guard Cutter.

FILES

Three new files have been added to the SMP and one existing file has been modified. The new new files are: (1) Load Coefficient file (LCOFIL,TAPE4); (2) Load Response Amplitude Operator file (LRAFIL,TAPE10); and (3) Severe Motion file (SEVFIL,TAPE14). The existing file that was changed is the RMS/T_{OE} file (RMSFIL,TAPE13). A descripton of each file as to its contents and where it is generated and/or accessed in SMP is presented next. It should be noted that files in SMP are identified by both name and number. The user can catalog and/or attach files only by using the tape numbers.

(1) Load Coefficient file - LCOFIL (TAPE4)

This file is generated in subroutine COFOUT when the program option (OPTN in Data Card Set 2) is either 2 or 3 and the load option (NLOAD in Data Card Set 6) is made greater than zero. This file must be attached when the user selects OPTN greater than 3 and NLOAD is greater than zero.

The file contains the sectional heave exiting force, added-mass, and damping for each station on the ship. This file is read in subroutine RAOPHS for the rms/toe calculations and in subroutine LRAOUT to print out the load response amplitude operators.

(2) Load Response Amplitude Operator file - LRAFIL (TAPE10)

This file is generated in subroutine LRAOUT and contains the response amplitude operators for the vertical shear force and vertical bending moment for load stations selected by the user. This file can be cataloged by the user for the purpose of transferring this information to some other computer program.

(3) Severe Motion file - SEVFIL (TAPE14)

This is a random access file generated in subroutine RMSOUT that

contains the Response Statistical Values/Encountered Modal Periods (RSV/T_{OE}) for heave, pitch, sway, roll, yaw, and the vertical and lateral accelerations for up to four point locations specified by the user. This file is read in subroutine SEVMOT, which prints out the Severe Motion Tables.

(4) RMS/T_{OE} file - RMSFIL (TAPE13)

This file contains the root mean square (RMS) values and the encountred modal periods for all motions defined by the user in the input to SMP. This file already exists in SMP but was modified to add new responses for fins, fin angle and fin velocity, as well as the vertical shear force and vertical bending moment for up to 10 stations specified by the user.

SOURCE CODE MODIFICATIONS

The Standard Ship Motion Program, SMP, was written in FORTRAN IV for the CONTROL DATA CORPORATION, CDC, computers at DTNSRDC. The listing of the SMP source code was provided in Appendix I of Reference 1. Each line in this listing contains 80 columns. The FORTRAN source code is contained in the first 72 columns. In addition, a subroutine name and sequence number are provided in columns 73 through 80.

A batch editor called UPDATE[8] was used to assemble the FORTRAN source code, subroutine names, and sequence numbers. The same editor was used to generate the changes to SMP described in this report. A listing of these changes is provided in Appendix A.

The changes include both UPDATE editing commands as well as new FORTRAN source code. The editing commands are identified by an asterisk in column 1. The editing commands reference specific lines in the SMP listing by the subroutine names and sequence numbers associated with these lines. A description of these update editing commands follows:

*ID SMP84	- The name SMP84 is given to the set of modifications
*I "NAME".N	- The FORTRAN instructions which follow this command are inserted in subroutine "NAME" after line N
*D "NAME".N(,M)	- Line N (optionally lines N through M) in subroutine "NAME" are to be deleted. Any

FORTRAN instructions which follow this command are inserted after the deletion

*AF - New FORTRAN subroutines which follow this command are appended to the end of the SMP source code

*DECK "NAME" - Name to be assigned to the Fortran instructions which follow this card

A listing of the segmentation cards required to load SMP84 is provided in Table 19.

DISK PACK STORAGE OF SMP UPDATES

Permanent storage of SMP and its UPDATES is maintained at DTNSRDC on the CDC CYBER 176 computer. Access to SMP and related files can be obtained by attaching a disk pack and copying the desired file to the main disk memory. The following is an example of the CDC control cards required to retrieve SMP84 from the disk pack:

```
CHZM,CM55000,T5,P3.
CHARGE,CHZM,XXXX00000.
PAUSE. JOB REQUIRES DISK PACK DV4901
MOUNT,VSN=DV4901,SN=TAPK06.
ATTACH,A,SMP84ABSOLUTE,ID=CHZM,SN=TAPK06.
REQUEST,SMP84,*PF.
COPYE,A,SMP84.
CATALOG,SMP84,SMP84ABSOLUTE,ID=CHZM,MR=1.
EOF
```

Examples of CDC control cards required to run various options of SMP can be found in Appendix E of Reference 1. The core requirement to run SMP84 is now 150000 octal. This represents a change from 100000 octal required to run SMP81.

The CDC-6700 computer at DTNSRDC has been replaced by a CDC CYBER-176 computer which is 10 times faster than the CDC-6700. Thus the SMP run times specified in Appendix E of Reference 1 should be reduced by a factor of 10.

The following files associated with the SMP UPDATES are stored on the disk pack and are available to the user:

1. SMP84ABSOLUTE - The absolute version of SMP84 used for production running.
2. SMP84 CHANGES - The file containing the 1984 UPDATE modifications to SMP81.

3. SMP84UPDATE - The UPDATE file containing the original SMP81 source code as well as the 1984 UPDATES.

4. SMP84COMPILE - The source file for SMP84.

5. SMP84OBJECT - The object file for SMP84.

6. SMP84SEGCARDS - The segmentation loader cards for SMP84.

7. SMP84LIBRARY - The library of object subroutines for SMP84.

These seven files are stored on Disk Pack TAPK06 and user ID=CHZM. The setname (SN) for this disk pack is TAPK06 and the Volume Serial Number (VSN) is DV4901. All seven files can be copied to the main disk memory using the COPYE utility.

For further information regarding CDC control cards, disk packs, and copy utilities, the user is referred to the DTNSRDC Computer Center CDC Reference Manual[7].

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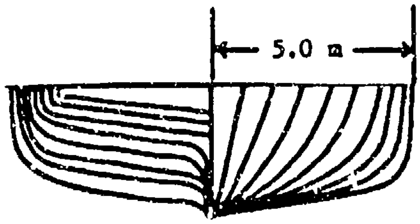
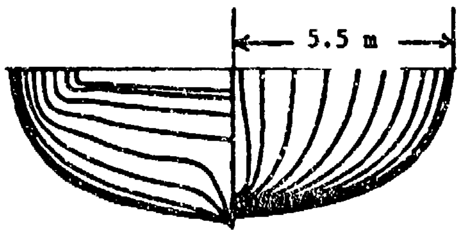
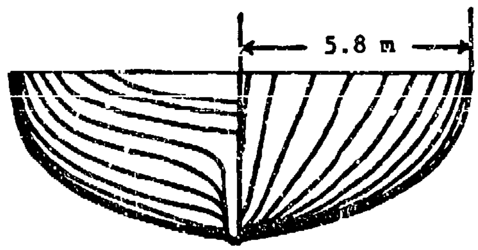


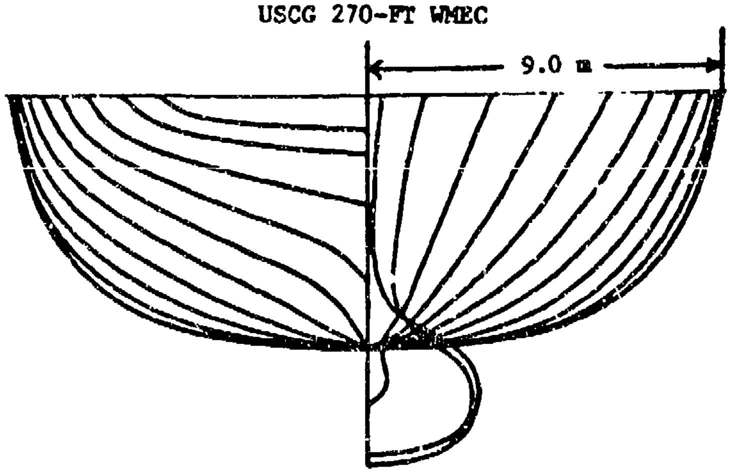
USCG 210-FT WMEC



DE-1006



USCG 270-FT WMEC



DDG-51

Figure 1 -- Computer-Generated Body Lines

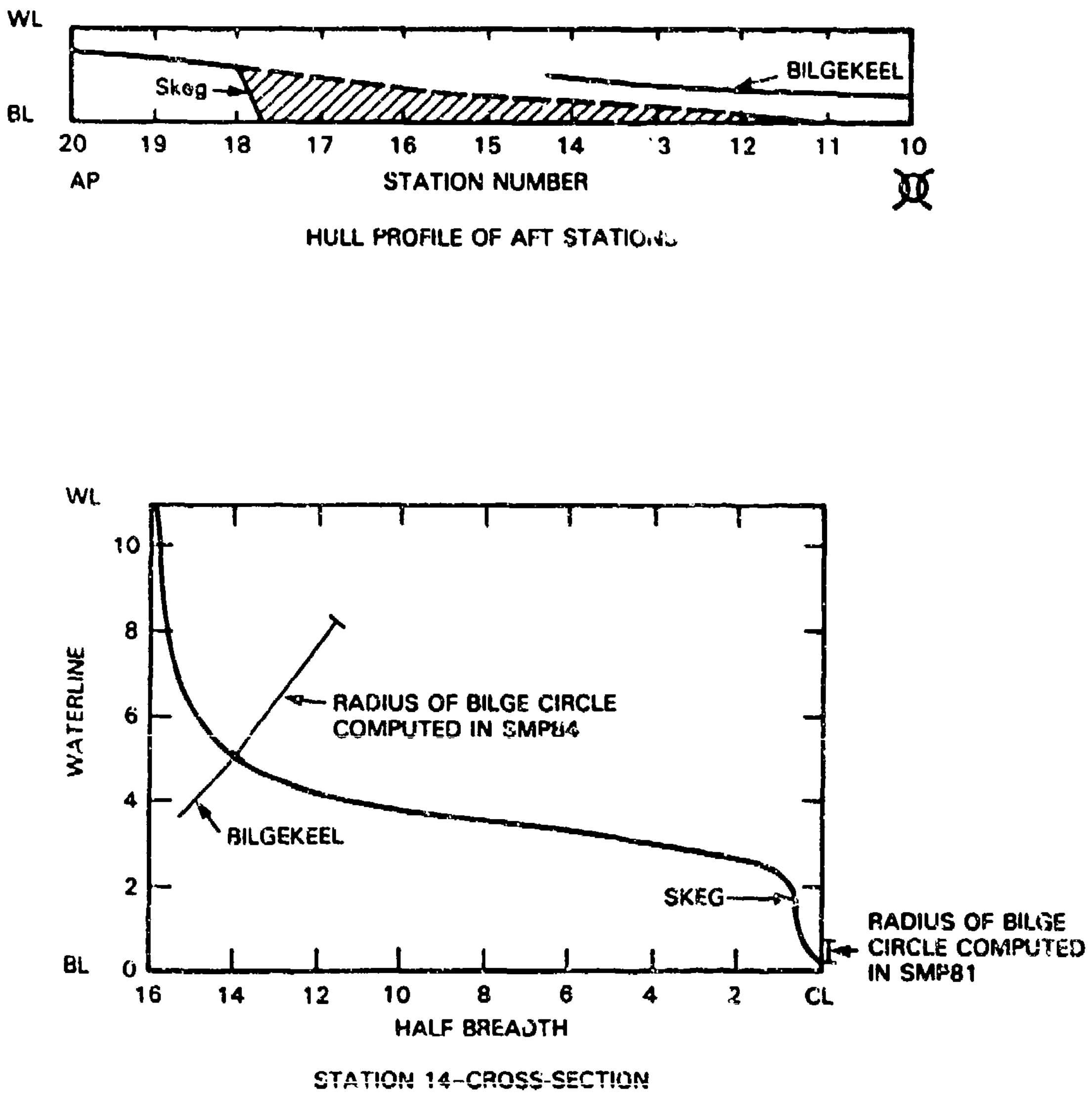


Figure 2 - Example of the Determination of the Radius of the Bilge Circle in SMP81 and SMP84 for a Station where the Bilge Keel Overlaps the Skeg

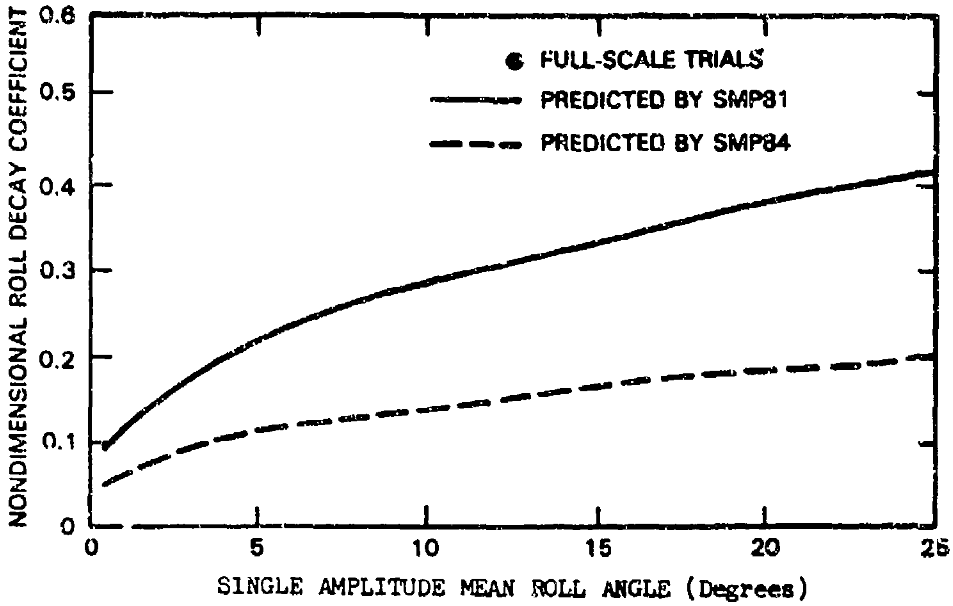


Figure 3a - Bilge Keel Component of Roll Damping

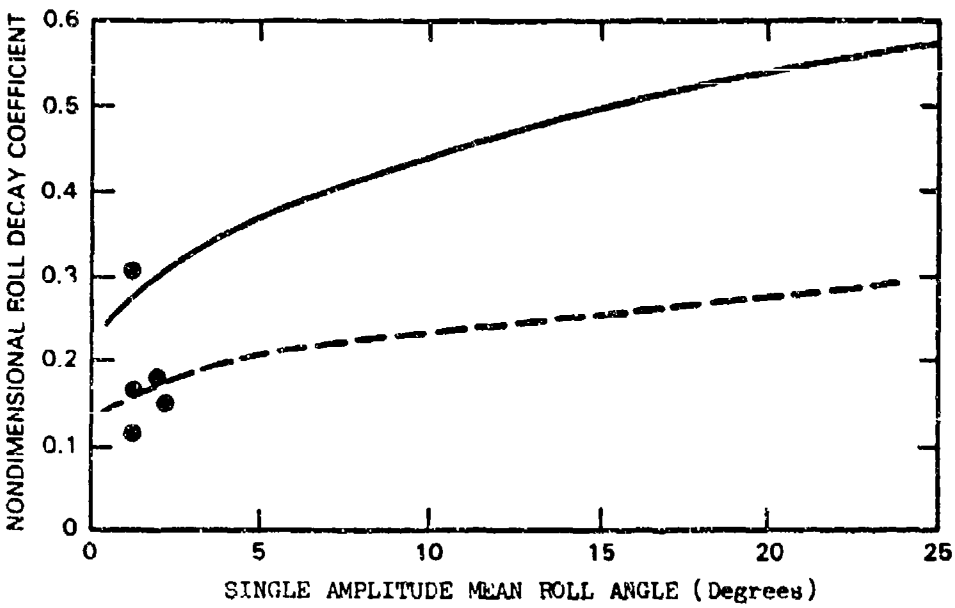


Figure 3b - Total Roll Damping

Figure 3 - Example of the Change in Roll Damping Coefficient Due to the Bilge Keel/Skeg Correction for the USCG 210-ft Medium Endurance Cutter (WMEC) for a Ship Speed of 16 Knots

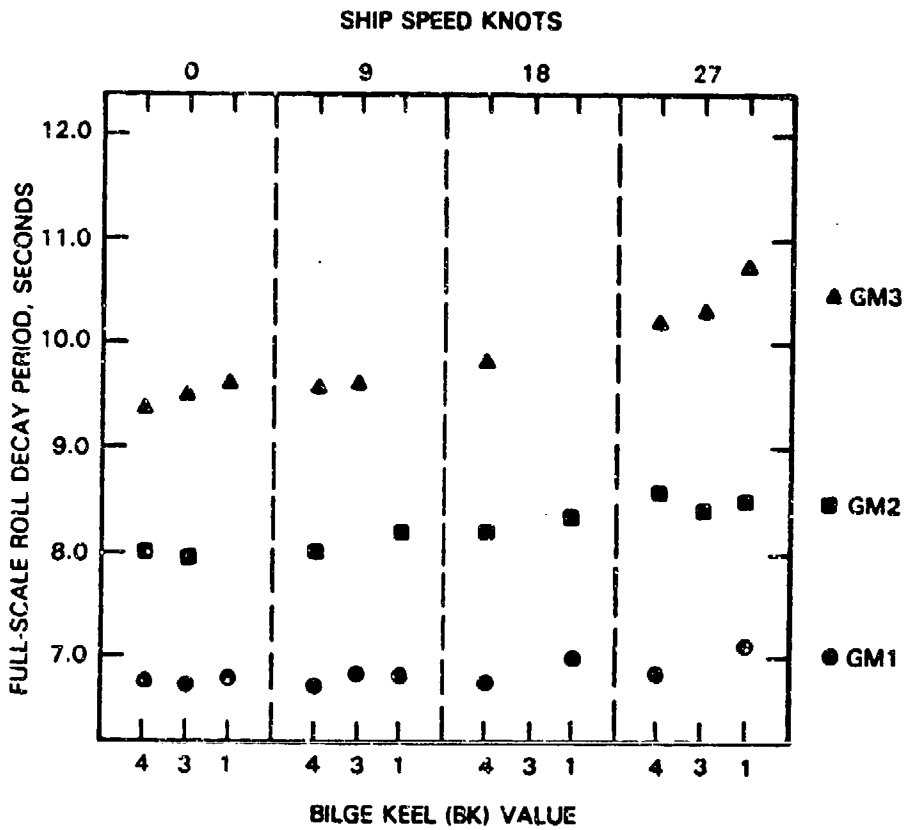


Figure 4 - Variations in the Measured Roll Periods for the DE-1006 at Three GM Values, Three Bilge Keel Configurations, Across Speed (from Reference 3)

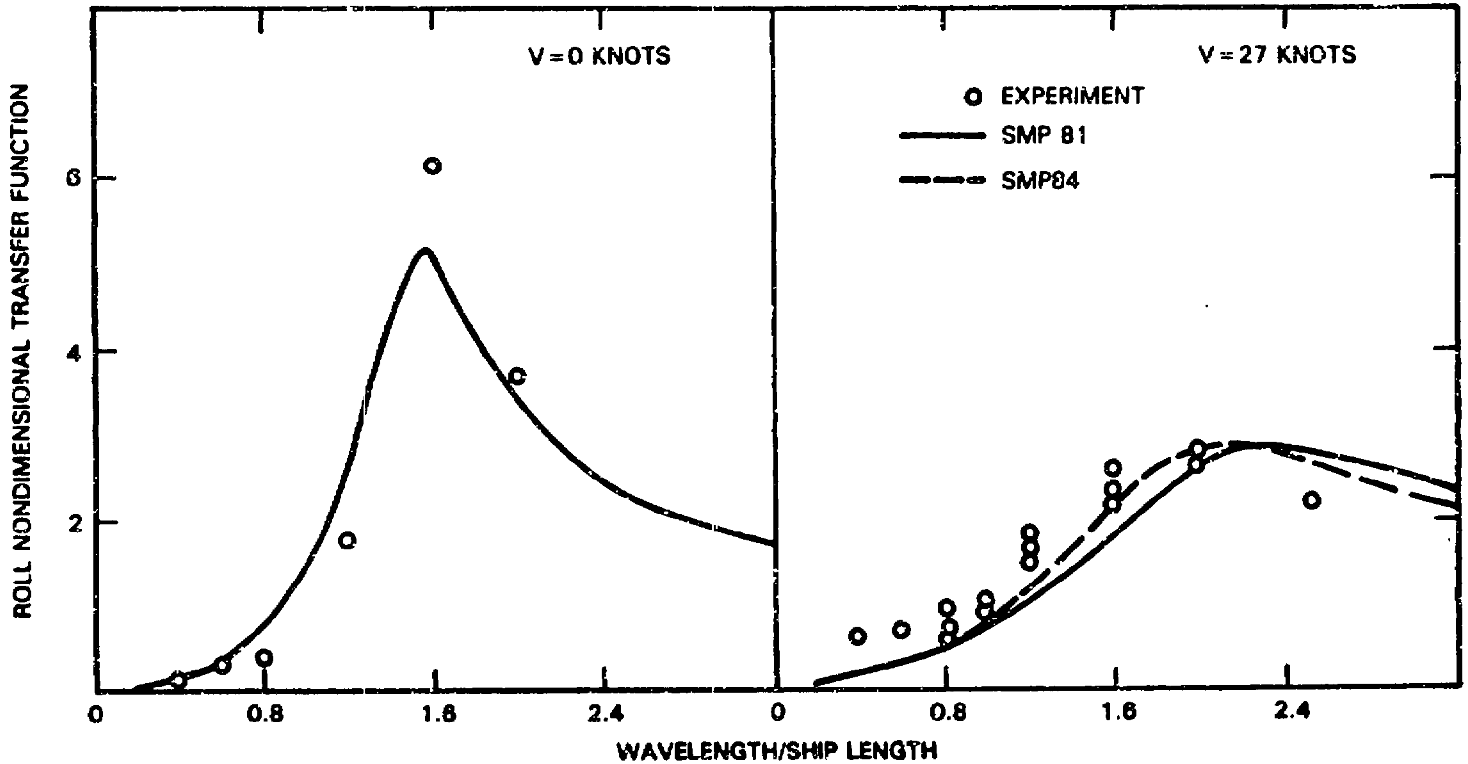


Figure 5 - Comparison of Predicted (SMP84 and SMP81) and Measured Nondimensional Roll Transfer Functions for the DE-1006 at 0 and 27 Knots in Beam Waves for GM3, BK1

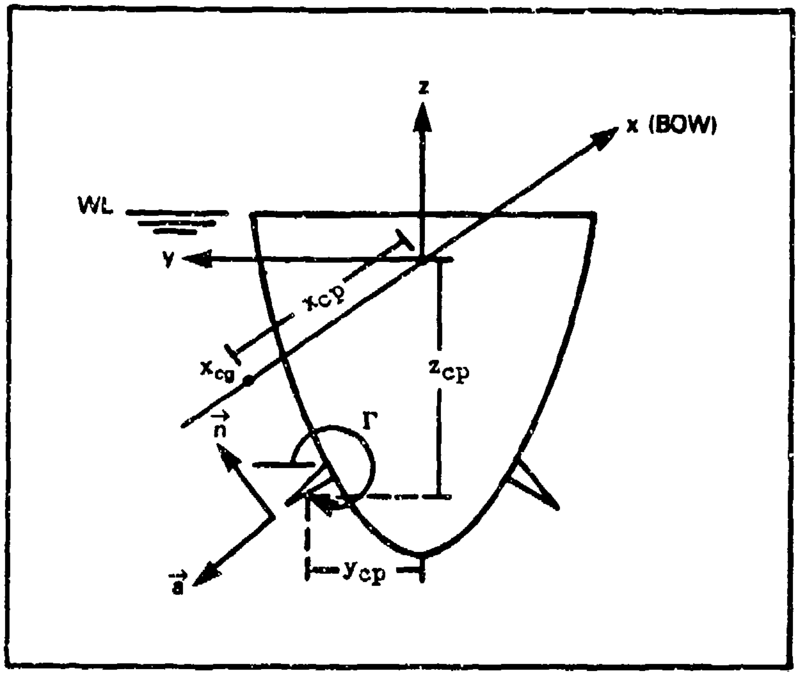


Figure 6 - Definition of Fin Position Vector, $\vec{r}_{cp}$, Angle Γ, Unit Axial Vector $\vec{a}$, and Unit Normal Vector $\vec{n}$

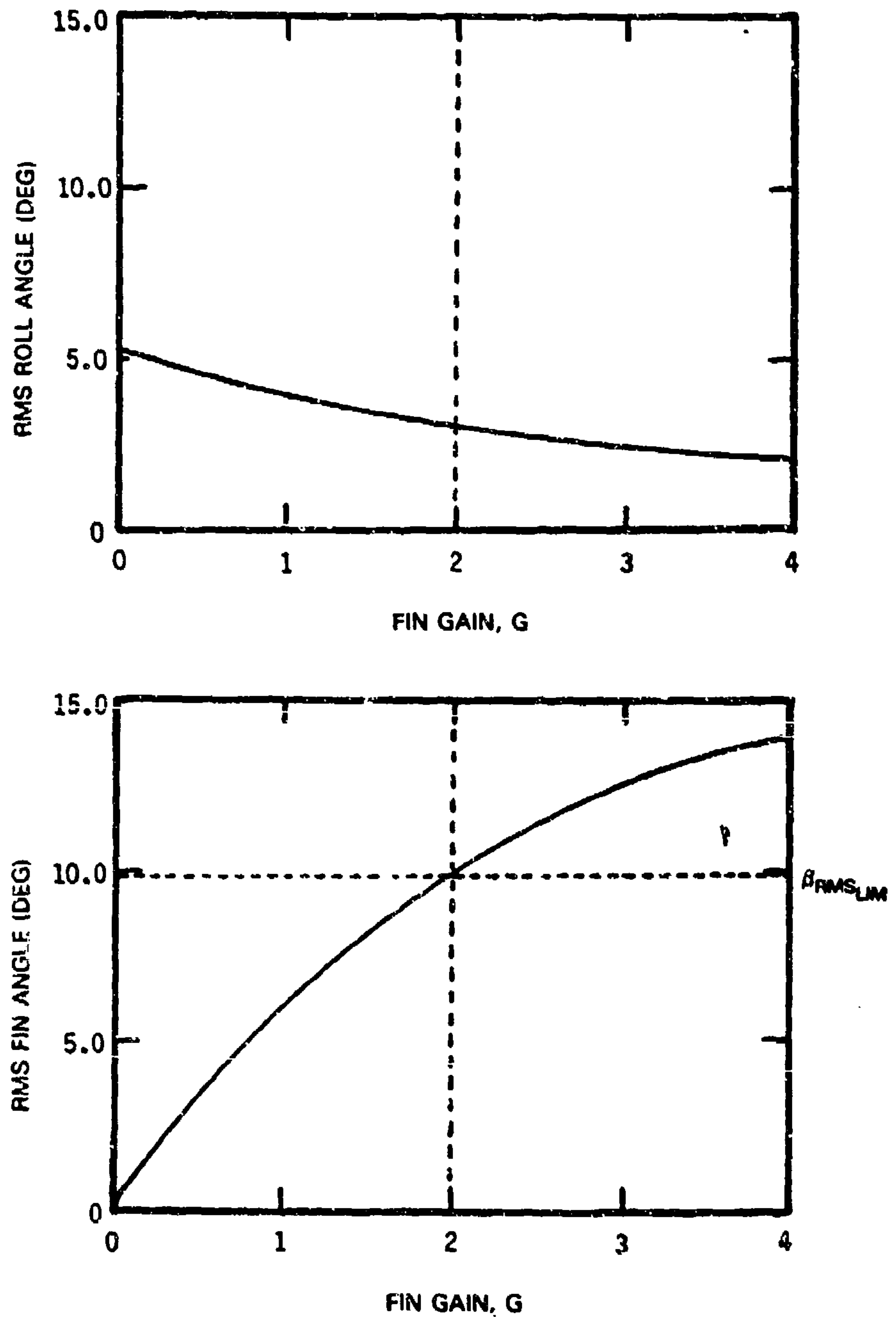


Figure 7 - Determination of Fin Gain for the USCGC BEAR at 15 Knots at 105° Heading in Shortcrested Seas with Significant Wave Height of 13 Feet (4 Meters) and Modal Wave Period of 9 Seconds

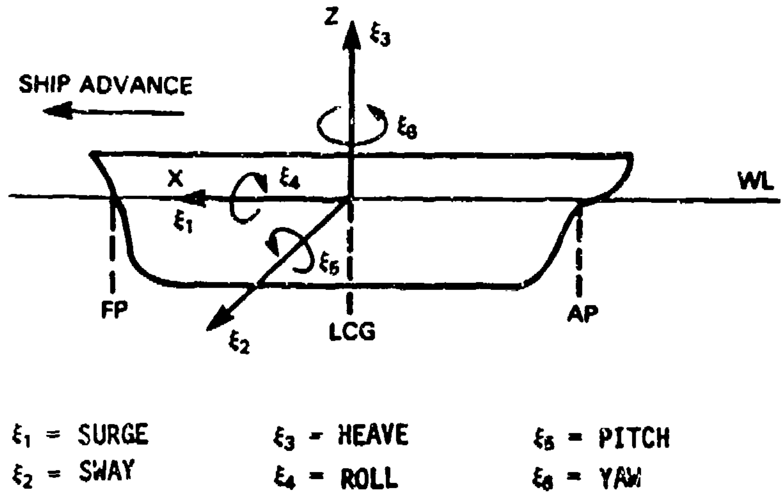


Figure 8a - Sign Convention of Translatory and Angular Displacements

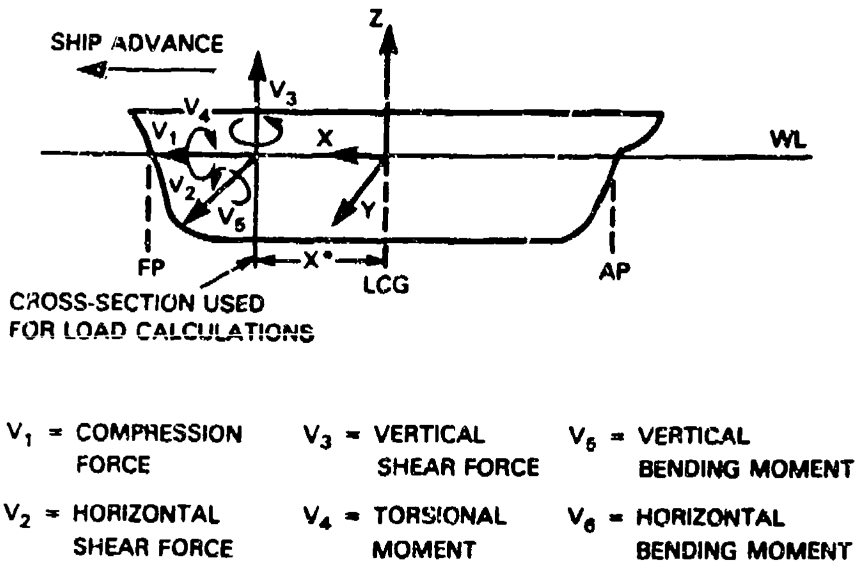


Figure 8b - Sign Convention of Dynamic Wave-Load Components

Figure 8 - Sign Conventions of Motions and Loads

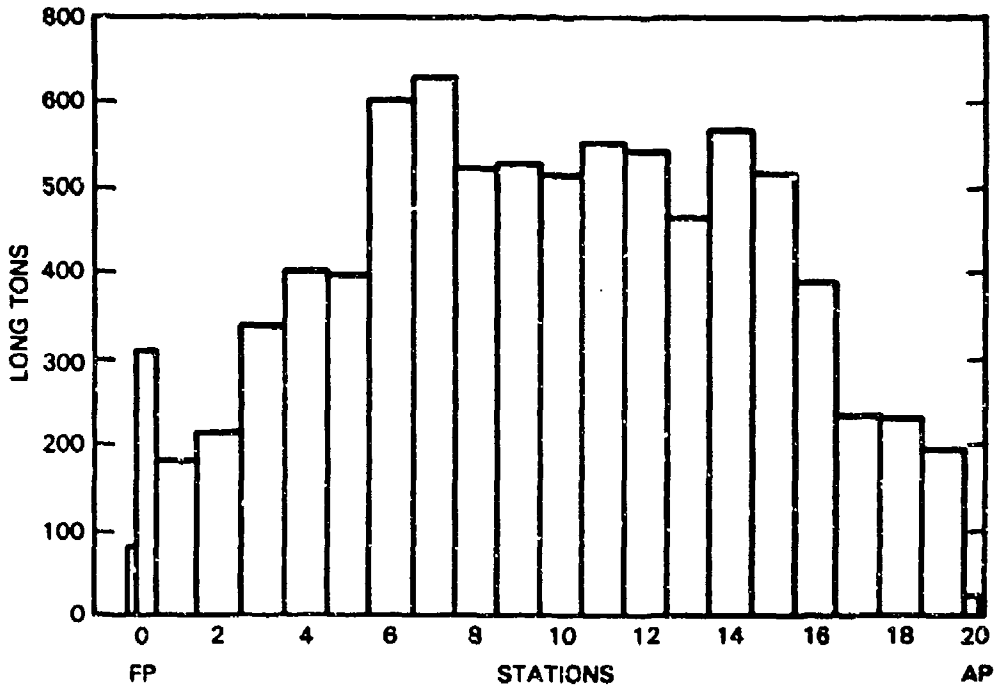


Figure 9 - Weight Distribution Curve for the DDG-51

TABLE 1 - SHIP PARTICULARS

	USCG 210-ft WMEC	DE-1006	USCG 270 ft WMEC	DDG-51
Length (L_{PP}), meters	61.0	93.9	77.7	142.0
Beam, (B), meters	10.1	11.0	11.6	18.0
Draft (T), meters	3.3	3.7	4.2	6.3
Displacement (Δ) S.W., metric tons	1025.2	1054.2	1818.7	8560.2
Metacentric Height (GM), %B	6.1	6.3	8.2	8.1
Center of Gravity (KG), %B	45.5	43.5	44.5	41.3
LCG*, %L_{PP}	51.6	51.7	51.3	50.1
Natural Roll Period, (T_ϕ), seconds	10.7	9.3	10.4	13.4
Pitch Gyradius (K_θ), %L_{PP}	25.0	25.0	24.0	25.0
Roll Gyradius, (K_ϕ), %B	38.0	32.1	41.1	40.0
Yaw Gyradius (K_ψ), %L_{PP}	25.0	25.0	25.0	25.0
Block Coefficient (C_B)	0.49	0.51	0.47	0.52
Bilge Keel Length, %L_{PP}	32.5	29.6	20.4	28.3
Bilge Keel Span, meters	0.59	0.47	0.61	0.91
Fin Area, s_q. meters	—	—	2.33	—

*Referenced to F.P.

TABLE 2 - NOMINAL VALUES OF FIN CONTROLLER COEFFICIENTS, K_j, FIN SERVO COEFFICIENTS, a_j, AND FIN CONTROLLER COMPENSATION COEFFICIENTS, b_j

$K_1 = 1.0$	$a_1 = 1.0$	$b_1 = 1.0$
$K_2 = 2.5$	$a_2 = 0.16$	$b_2 = 0.025$
$K_3 = 1.0$	$a_3 = 0.63$	$b_3 = 0.052$

TABLE 3 - SMP INPUT DECK FOR USCG 270-FT MEDIUM ENDURANCE CUTTER (WMEC) - BEAR

INPUT CARDS

```
                                                          COLUMN
               1         2         3         4         5         6         7         8
CARD  12345678901234567890123456789012345678901234567890123456789012345678901234567890

  1   UNITED STATES COAST GUARD 270-FT WMEC FULL-SCALE SIMULATION (STERN TRIM - 3/84)
  2       5     1
  3   FEET      1.9905    32.1725   1.2791E-05
  4   255.0     38.0      13.776    1790.     15.0      15.0
  5   3.10      0.0       16.92     0.24      0.411     0.25
  6      21
  7    0.25          8
  8    0.25     0.00      0.20      0.28      0.30      0.40      0.50      0.60      0.75
  9    0.25     6.89      7.28      8.28      9.28      10.28     11.48     12.23     13.776
 10    1.00          8
 11    1.00     0.00      0.40      1.00      1.40      1.80      2.15      2.60      2.90
 12    1.00     1.56      2.26      4.26      6.26      8.26      10.26     12.26     13.776
 13    2.00          8
 14    2.00     0.00      1.40      2.40      3.20      4.00      4.80      5.50      6.00
 15    2.00     0.34      2.24      4.24      6.24      8.24      10.24     12.24     13.776
 16    3.00          8
 17    3.00     0.00      2.40      3.93      5.35      6.60      7.50      8.50      9.20
 18    3.00     0.21      2.21      4.21      6.21      8.21      10.21     12.21     13.776
 19    4.00          8
 20    4.00     0.00      3.30      5.60      7.50      9.00      10.30     11.40     12.10
 21    4.00     0.18      2.18      4.18      6.18      8.18      10.18     12.18     13.776
 22    5.00          8
 23    5.00     0.00      4.30      7.20      9.50      11.25     12.60     13.70     14.40
 24    5.00     0.16      2.16      4.16      6.16      8.16      10.16     12.16     13.776
 25    6.00          8
 26    6.00     0.00      5.40      8.80      11.30     13.20     14.50     15.50     16.15
 27    6.00     0.13      2.13      4.13      6.13      8.13      10.13     12.13     13.776
 28    7.00          8
 29    7.00     0.00      6.40      10.30     12.90     14.70     16.00     16.90     17.40
 30    7.00     0.105     2.105     4.105     6.105     8.105     10.105    12.105    13.776
 31    8.00          8
 32    8.00     0.00      7.40      11.60     14.30     16.00     17.10     17.80     18.20
 33    8.00     0.08      2.08      4.08      6.08      8.08      10.08     12.08     13.776
 34    9.00          8
 35    9.00     0.00      8.00      12.60     15.30     16.90     17.80     18.40     18.75
 36    9.00     0.05      2.05      4.05      6.05      8.05      10.05     12.05     13.776
 37   10.00          8
 38   10.00     0.00      8.60      13.20     16.00     17.50     18.40     18.90     18.90
 39   10.00     0.03      2.03      4.03      6.03      8.03      10.03     12.03     13.776
 40   11.00          8
 41   11.00     0.00      4.00      8.50      13.30     16.00     17.70     18.50     19.00
 42   11.00     0.00      0.75      2.00      4.00      6.00      8.00      10.00     13.776
 43   12.00          8
 44   12.00     0.00      4.00      7.75      12.60     15.65     17.43     18.30     19.00
 45   12.00     0.17      0.97      1.97      3.97      5.97      7.87      9.97      13.776
```

TABLE 3 (CONTINUED)

INPUT CARDS

```
                                     COLUMN
              1         2         3         4         5         6         7         8
CARD 12345678901234567890123456789012345678901234567890123456789012345678901234567890

 46   13.00        8
 47   13.00     0.00      0.87      0.90      1.40      6.00      12.00     16.95     18.90
 48    13.00    0.00      0.30      0.70      0.90      2.10      4.30      7.95      13.776
 49   14.00        9
 50   14.00     0.00      0.45      0.90      0.95      5.00      8.60      13.35     17.55     18.60

 51    14.00    -0.08     -0.08     0.42      0.92      2.92      3.92      5.92      9.92      13.776
 52   15.00        9
 53   15.00     0.00      0.45      0.95      1.00      5.00      10.25     14.40     16.60     18.15
 54    15.00    -0.105    -0.106    0.895     1.895     4.395     5.895     7.895     9.895     13.776
 55   16.00        9
 56   16.00     0.00      0.45      0.95      1.00      1.12      5.00      11.30     15.00     17.40
 57    16.00    -0.13     -0.13     0.87      1.87      2.87      6.22      7.67      9.87      13.776
 58   17.00       10
 59   17.00     0.00      0.45      0.95      1.05      1.20      1.35      5.00      10.00     14.00     16.40
 60    17.00    -0.16     -0.16     0.84      1.84      2.84      5.84      7.84      8.99      10.64     13.776
 61   18.00        8
 62   18.00     0.00      2.00      4.00      7.10      10.00     12.00     14.00     15.10
 63   18.00     8.72      8.92      9.22      9.82      10.52     11.22     12.22     13.776
 64   19.00        7
 65   19.00     0.00      2.60      4.80      7.00      8.60      11.20     13.45
 66    19.00    10.19     10.49     10.79     11.24     11.59     12.24     13.776
 67   19.75        5
 68   19.75     0.00      2.00      5.00      8.00      11.00
 69    19.75    11.17     11.37     11.77     12.27     13.776
 70       1
 71       4     9.255          13.333         2.0
 72   10.0      14.40          4.70           57.50
 73   11.0      14.45          4.65           60.00
 74   12.0      14.05          4.85           56.25
 75   13.0      13.30          5.05           60.00
 76       1
 77   12.60     17.58          18.04          0.00           0.00           0.00           9.00
 78       1
 79   19.11     19.76          6.50           10.08          10.93
 80   19.20     19.48          6.50           0.50           0.80
 81       0
 82       1    1    1
 83   0.        2.
 84   1.        2.5            1.
 85   1.        .16            .025
 86   1.        .63            .092
 87   2.529     2.118
 88   7.9[illegible]   9.09           12.75          8.00           8.00
 89   7.72      7.95           15.97          0.876          1.20
```

TABLE 3 (CONTINUED)

INPUT CARDS

```
                                                COLUMN
              1         2         3         4         5         6         7         8
CARD 12345678901234567890123456789012345678901234567890123456789012345678901234567890
 90      5
 91      1    CREWS MESS                          11.45     -17.8     28.3
 92      2    CSC/PILOTHOUSE                      5.5       4.25      48.3
 93      3    HELICOPTER FLIGHT DECK              13.08     -3.4      29.7
 94      4    COMMUNICATIONS CENTER               4.24      4.90      14.30
 95      5    SMR LOCATION (GUN MOUNT)            1.22      0.0       27.9
 96      4
 97      1    STATION 3 (SLAMMING)    1    3.0    0.0       0.0       8.40
 98      2    STATION 2 (DECK WET)    3    2.0    0.0       33.2
 99      3    STATION 0 (DECK WET)    3    0.0    0.0       34.4
100      4    FOREFOOT (EMERGENCE)    2    0.55   0.0       2.0
101      1    2.0       SIGNIFICANT
102  13.0
103  STOP
```

TABLE 4 - EXAMPLE OF INPUT CARD DESCRIPTION FOR DATA CARD SET 11 FOR ACTIVE FINS

DATA CARD SET 11 - FIN PARTICULARS

NFNSET	IACTFN	IFCLCS
1	1	1

SHIP SPEED (KNOTS) =	0.000	15.000	
FIN GAIN FACTORS =	0.000	2.000	
CONTROLLER COEFF. =	1.000	2.500	1.000
SERVO COEFFICIENTS =	1.000	.160	.025
COMPENSATION COEFF. =	1.000	.630	.092

CORRECTED FIN LIFT CURVE SLOPE

SHIP SPEED (KNOTS) =	0.000	15.000
FNSET 1 - FCLCS =	2.529	2.118

FNSET	LOCATION	FWDSTN	AFTSTN	HLFRN	FWDWL	AFTWL
1	ROOT	7.5500	8.0900	12.7500	8.0000	5.0000
1	TIP	7.7200	7.9500	15.9700	.8780	1.2000

TABLE 5 - NONDIMENSIONAL ROLL DECAY COEFFICIENTS FOR USCGC BEAR

UNITED STATES COAST GUARD 270-FT WMEC FULL-SCALE SIMULATION (STERN TRIM - 3/84)

SHIP PARTICULARS

LPP =	255.00	GM =	3.10
BEAM =	38.00	KROLL =	.412
DRAFT =	13.78	WPHI =	.604
DISPLM =	1790.	TPHI =	10.40

HULL AND APPENDAGE PARTICULARS

	Q	GAMMA	MCHORD	MSPAN	AREA	XCP	YCP	ZCP	YHAT	EAR	LCS
HULL	1.	-90.0	255.00	13.78	3312.58	10.97	0.00	0.00	0.00	.108	.170
SKEG	1.	-90.0	31.75	9.00	285.72	-73.10	0.00	-15.44	15.44	.567	.891
RUDDER	2.	-90.0	5.99	10.01	59.95	-114.84	6.50	-11.44	11.44	3.339	3.217
BILGEKEEL	2.	-52.9	81.29	2.00	103.99	-15.12	15.45	-12.07	18.31	.077	.121
FIN	2.	-50.9	4.91	5.11	25.02	[illegible]	14.36	-13.92	19.86	2.080	2.528

SHIP ROLL DECAY COEFFICIENT, N

SHIP SPEED (KNOTS)	MEAN ROLL ANGLE (SA) (DEGREES)							
	.5	1.0	2.5	5.0	10.0	15.0	25.0	40.0
0.	.011	.015	.022	.032	.048	.062	.090	.131
15.	.115	.118	.123	.128	.136	.142	.151	.163

TABLE 6 - UNSTABILIZED ROLL ANGLE FOR USCGC BEAR

UNITED STATES COAST GUARD 270-FT WMEC FULL-SCALE SIMULATION (STERN TRIM - 3/84)

SHORTCRESTED
SIGNIFICANT WAVE HEIGHT = 13.00 FEET

ROLL ANGLE
(DEG)

SIGNIFICANT VALUE / ENCOUNTERED MODAL PERIOD (TOE)

SHIP HEADING ANGLE IN DEGREES

V	TO	HEAD 0	15	30	45	60	75	STBD BEAM 90	105	120	135	150	165	FOLLOW 180
0	9	7.74/10	8.05/10	8.65/10	9.77/10	10.55/10	11.06/10	11.23/10	11.04/10	10.51/10	9.71/10	8.78/10	7.98/10	7.65/10
	11	9.31/11	9.69/11	10.60/11	11.65/11	12.55/11	13.13/11	13.32/11	13.11/11	12.51/11	11.60/11	10.54/11	9.61/11	9.23/11
	13	8.96/11	9.33/11	10.22/11	11.24/11	12.11/11	12.68/11	12.87/11	12.66/11	12.08/11	11.20/11	10.16/11	9.28/11	8.89/11
	15	8.03/11	8.37/11	9.18/11	10.11/11	10.91/11	11.43/11	11.60/11	11.41/11	10.88/11	10.07/11	9.13/11	8.31/11	7.97/11
	17	7.04/11	7.34/11	8.05/11	8.89/11	9.60/11	10.07/11	10.22/11	10.06/11	9.58/11	8.85/11	8.01/11	7.29/11	6.99/11
15	9	1.68/ 9	1.98/10	2.68/10	4.60/10	6.44/11	8.21/11	9.56/11	10.37/11	10.58/11	10.19/14	9.31/14	8.34/14	7.92/14
	11	2.57/10	2.92/10	3.84/11	5.20/11	6.72/11	8.06/11	9.03/11	9.53/11	9.52/11	8.99/11	8.06/14	7.09/14	6.67/14
	13	3.11/11	3.42/11	4.22/11	5.32/11	6.47/11	7.45/11	8.11/11	8.36/11	8.19/11	7.60/11	6.72/14	5.83/14	5.44/14
	15	3.17/11	3.44/11	4.11/11	4.99/11	5.89/11	6.61/11	7.05/11	7.16/11	6.91/11	6.35/11	5.55/14	4.77/14	4.43/14
	17	2.98/11	3.20/11	3.75/11	4.47/11	5.19/11	5.74/11	6.06/11	6.08/11	5.82/11	5.30/14	4.60/14	3.93/14	3.64/14

TABLE 7 - STABILIZED ROLL ANGLE FOR USCGC BEAR

UNITED STATES COAST GUARD 270-FT WMEC FULL-SCALE SIMULATION (STERN TRIM - 3/84)

SHORTCRESTED
SIGNIFICANT WAVE HEIGHT = 13.00 FEET

ROLL ANGLE
(DEG)

SIGNIFICANT VALUE / ENCOUNTERED MODAL PERIOD (TOE)

V	TO	HEAD 0	15	30	45	60	75	STBD BEAM 90	105	120	135	150	165	FOLLOW 180
0	9	7.73/10	8.06/10	8.85/10	9.77/10	10.55/10	11.06/10	11.23/10	11.04/10	10.51/10	9.71/10	8.78/10	7.98/10	7.65/10
	11	9.31/11	9.69/11	10.60/11	11.65/11	12.55/11	13.13/11	13.32/11	13.11/11	12.51/11	11.60/11	10.54/11	9.61/11	9.22/11
	13	8.96/11	9.33/11	10.22/11	11.24/11	12.11/11	12.67/11	12.86/11	12.68/11	12.08/11	11.19/11	10.16/11	9.26/11	8.89/11
	15	8.03/11	8.37/11	9.18/11	10.11/11	10.91/11	11.43/11	11.60/11	11.41/11	10.88/11	10.07/11	9.12/11	8.31/11	7.97/11
	17	7.04/11	7.34/11	8.06/11	8.89/11	9.60/11	10.07/11	10.22/11	10.05/11	9.58/11	8.85/11	8.01/11	7.29/11	6.99/11
15	9	1.50/ 8	1.69/ 8	2.24/ 9	3.10/10	4.11/10	5.03/10	5.73/10	6.13/10	6.18/14	5.90/14	5.37/14	4.82/14	4.58/14
	11	1.88/ 9	2.07/10	2.58/10	3.31/10	4.09/10	4.79/10	5.28/10	5.51/10	5.46/14	5.13/14	4.61/14	4.09/14	3.87/14
	13	1.99/10	2.16/10	2.60/10	3.19/10	3.81/10	4.32/10	4.66/10	4.78/14	4.65/14	4.32/14	3.84/14	3.38/14	3.18/14
	15	1.92/10	2.06/10	2.43/10	2.91/10	3.40/11	3.79/11	4.02/11	4.07/14	3.93/14	3.61/14	3.18/14	2.78/14	2.61/14
	17	1.75/10	1.87/11	2.18/11	2.58/11	2.97/11	3.28/11	3.45/11	3.46/14	3.31/14	3.03/14	2.65/14	2.31/14	2.17/14

TABLE 8 - STABLIIZED ROLL VELOCITY FOR USCGC BEAR

UNITED STATES COAST GUARD 270-FT WMEC FULL-SCALE SIMULATION (STERN TRIM - 3/84)

SHORTCRESTED
SIGNIFICANT WAVE HEIGHT = 13.00 FEET

ROLL VELOCITY
(DEG/SEC)

SIGNIFICANT VALUE / ENCOUNTERED MODAL PERIOD (TOE)

V	TO	SHIP HEADING ANGLE IN DEGREES												
		HEAD 0	15	30	45	60	75	STBD BEAM 90	105	120	135	150	165	FOLLOW 180
0	9	4.83/10	5.04/10	5.56/10	6.17/10	6.69/10	7.03/10	7.14/10	7.02/10	6.66/10	6.13/10	5.61/10	4.98/10	4.76/10
	11	5.39/11	5.83/11	6.30/11	7.04/11	7.59/11	7.95/11	8.07/11	7.94/11	7.57/11	7.00/11	6.34/11	5.77/11	5.53/11
	13	5.29/11	5.51/11	6.04/11	6.65/11	7.17/11	7.51/11	7.62/11	7.50/11	7.15/11	6.62/11	6.00/11	5.47/11	5.24/11
	15	4.70/11	4.89/11	5.37/11	5.91/11	6.38/11	6.68/11	6.78/11	6.67/11	6.36/11	5.89/11	5.33/11	4.85/11	4.66/11
	17	4.09/11	4.27/11	4.68/11	5.16/11	5.57/11	5.84/11	5.93/11	5.83/11	5.56/11	5.14/11	4.65/11	4.23/11	4.06/11
15	9	1.48/ 7	1.61/ 7	1.97/ 8	2.49/10	3.04/10	3.49/10	3.78/10	3.87/10	3.75/10	3.44/10	2.98/10	2.50/14	2.29/14
	11	1.55/ 9	1.67/ 9	1.99/ 9	2.41/10	2.84/10	3.16/10	3.34/10	3.36/10	3.20/10	2.90/10	2.47/10	2.06/14	1.87/14
	13	1.48/10	1.58/10	1.64/10	2.18/10	2.50/10	2.74/10	2.85/10	2.82/10	2.65/10	2.37/10	2.00/14	1.65/14	1.50/14
	15	1.33/10	1.41/10	1.62/10	1.89/10	3.14/10	2.31/10	2.38/10	2.34/10	2.18/10	1.93/10	1.62/14	1.33/14	1.20/14
	17	1.16/10	1.23/10	1.40/10	1.62/10	1.81/10	1.95/10	1.99/10	1.94/10	1.80/10	1.59/10	1.33/14	1.09/14	.98/14

TABLE 9 - FIN ANGLE FOR USCGC BEAR

UNITED STATES COAST GUARD 270-FT WMEC FULL-SCALE SIMULATION (STERN TRIM - 3/84)

SHORTCRESTED
SIGNIFICANT WAVE HEIGHT = 13.00 FEET

FIN ANGLE
(DEG)

SIGNIFICANT VALUE / ENCOUNTERED MODAL PERIOD (TOE)

SHIP HEADING ANGLE IN DEGREES

V	TO	HEAD 0	15	30	45	60	75	STBD BEAM 90	105	120	135	150	165	FOLLOW 180
0	9	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**
	11	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**
	13	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**
	15	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**
	17	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**
15	9	6.82/ 7	7.46/ 8	9.28/ 8	11.97/10	14.92/10	17.47/10	19.22/10	19.98/10	19.67/10	18.33/10	15.19/14	14.01/14	13.05/14
	11	7.40/ 9	8.02/ 9	9.36/10	11.89/10	14.19/10	16.08/10	17.26/10	17.59/10	17.02/10	15.63/10	13.65/14	11.70/14	10.84/14
	13	7.26/10	7.79/10	9.16/10	10.96/10	12.74/10	14.12/10	14.89/10	14.94/10	14.26/10	12.95/14	11.19/14	9.52/14	8.80/14
	15	6.65/10	7.09/10	8.23/10	9.68/10	11.07/10	12.10/10	12.81/10	12.53/10	11.65/10	10.67/14	9.17/14	7.76/14	7.15/14
	17	5.88/10	6.25/10	7.19/10	8.38/10	9.49/10	10.29/10	10.64/10	10.50/10	9.88/14	8.85/14	7.57/14	6.39/14	5.88/14

TABLE 10 - FIN VELOCITY FOR USCGC BEAR

UNITED STATES COAST GUARD 270-FT WMEC FULL-SCALE SIMULATION (STERN TRIM - 3/84)

SHORTCRESTED
SIGNIFICANT WAVE HEIGHT = 13.00 FEET

FIN VELOCITY
(DEG/SEC)

SIGNIFICANT VALUE / ENCOUNTERED MODAL PERIOD (TOE)

SHIP HEADING ANGLE IN DEGREES

V	TO	HEAD 0	15	30	45	60	75	STBD BEAM 90	105	120	135	150	165	FOLLOW 180
0	9	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**
	11	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**
	13	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**
	15	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**
	17	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**	0.00/**
15	9	7.96/ 6	8.43/ 6	9.68/ 7	11.33/ 8	12.89/10	13.98/10	14.42/10	14.14/10	13.19/10	11.65/10	9.70/10	7.78/10	6.89/10
	11	7.14/ 8	7.54/ 8	8.60/ 9	9.93/ 9	11.14/10	11.94/10	12.17/10	11.81/10	10.90/10	9.54/10	7.87/10	6.26/10	5.53/14
	13	6.21/ 9	6.54/ 9	7.39/ 9	8.44/10	9.37/10	9.93/10	10.03/10	9.65/10	8.83/10	7.66/10	6.28/10	4.97/14	4.37/14
	15	5.27/10	5.54/10	6.23/10	7.06/10	7.78/10	8.19/10	8.22/10	7.86/10	7.15/10	6.17/10	5.03/10	3.96/14	3.48/14
	17	4.44/10	4.86/10	5.21/10	5.88/10	6.45/10	6.77/10	6.77/10	6.44/10	5.84/10	5.02/10	4.07/10	3.20/14	2.81/14

TABLE 11 - SMP INPUT DECK FOR DDG-51

I N P U T   C A R D S

COLUMN

CARD	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890			
	1	2	3	4	5	6	7	8			
1	HD.DAT DDG51 BY JMK		7/19/83	DRAFT - 20.69 FT		TRIM - 0.00 FT					
2	2	0	0	0	1						
3	FEET	1.9905	32.1740	.00001279							
4	466.0000	58.9221	20.6900	8500 [illegible]	15.0000	15.000	0.0000				
5	4.7700	0.1100	24.2400	.2500	.4000	.2500					
6	23	1									
7	0.0000	0	0								
8	0.0000	0.00									
9	0.0000	0.00									
10	.2500	10	0								
11	.2500	0.00	4.45	6.17	6.32	5.67	2.04	.48	.48	.69	1.18
12	.2500	-9.58	-9.04	-8.63	-2.37	.83	3.18	7.22	11.72	16.21	20.69
13	1.0000	10	0								
14	1.0000	0.00	4.25	7.95	8.19	4.99	2.27	2.27	2.83	3.66	4.74
15	1.0000	-8.76	-8.26	-6.20	-2.26	.58	3.82	8.07	12.33	16.54	20.69
16	2.0000	10	0								
17	2.0000	0.00	1.48	1.12	2.75	4.09	5.35	6.61	7.84	9.07	10.31
18	2.0000	-4.70	-2.95	.07	2.85	5.79	8.76	11.73	14.72	17.71	20.69
19	3.0000	10	0								
20	3.0000	0.00	2.54	4.57	6.40	8.12	9.78	11.38	12.83	14.24	15.60
21	3.0000	0.00	1.19	3.32	5.63	8.02	10.45	12.94	15.49	18.08	20.69
22	4.0000	10	0								
23	4.0000	0.00	3.09	5.76	8.32	10.60	12.90	14.96	16.86	18.61	20.21
24	4.0000	0.00	.97	2.87	4.98	7.27	9.72	12.31	15.00	17.80	20.69
25	5.0000	10	0								
26	5.0000	0.00	3.54	6.81	9.92	12.83	15.51	17.96	20.14	22.05	23.72
27	5.0000	0.00	.70	2.27	4.15	6.33	8.78	11.46	14.37	17.47	20.69
28	6.0000	10	0								
29	6.0000	0.00	3.88	7.62	11.19	14.53	17.57	20.25	22.54	24.47	26.11
30	6.0000	0.00	.44	1.60	3.20	5.24	7.70	10.56	13.73	17.13	20.69
31	7.0000	10	0								
32	7.0000	0.00	4.14	8.22	12.17	15.87	19.13	21.91	24.23	26.15	27.69
33	7.0000	0.00	.24	.97	2.22	4.10	6.65	9.73	13.16	16.94	20.69
34	8.0000	10	0								
35	8.0000	0.00	4.33	8.64	12.86	16.84	20.30	23.17	25.49	27.32	28.68
36	8.0000	0.00	.13	.56	1.49	3.16	5.77	9.01	12.65	16.58	20.69
37	9.0000	10	0								
38	9.0000	0.00	4.46	8.90	13.30	17.49	21.19	24.22	26.52	28.12	29.23
39	9.0000	0.00	.10	.43	1.19	2.66	5.14	8.40	12.22	16.37	20.69
40	10.0000	10	0								
41	10.0000	0.00	4.53	9.04	13.52	17.84	21.73	24.89	27.14	28.52	29.46
42	10.0000	0.00	.11	.46	1.17	2.51	4.80	8.03	11.95	16.26	20.69
43	11.0000	10	0								
44	11.0000	0.00	4.53	9.04	13.51	17.83	21.76	24.95	27.22	28.57	29.48
45	11.0000	0.00	.13	.52	1.23	2.58	4.84	8.03	11.83	16.25	20.69

TABLE 11 (CONTINUED)

INPUT CARDS

COLUMN
1 2 3 4 5 6 7 8
1234567890123456789012345678901234567890123456789012345678901234567890123456789

CARD											
46	12.0000	10	0								
47	12.0000	0.00	4.45	8.87	13.24	17.44	21.30	24.62	27.09	28.51	29.41
48	12.0000	0.00	.23	.82	1.74	3.23	5.44	8.41	12.10	16.32	20.69
49	13.0000	10	0								
50	13.0000	0.00	4.30	8.54	12.69	16.66	20.43	23.84	26.57	28.21	29.21
51	13.0000	0.00	.46	1.37	2.61	4.32	6.47	9.13	12.47	16.47	20.69
52	14.0000	10	0								
53	14.0000	0.00	4.05	7.99	11.83	15.56	19.19	22.62	25.54	27.56	28.77
54	14.0000	0.00	.86	2.23	3.83	5.71	7.75	10.12	13.07	16.71	20.69
55	15.0000	10	0								
56	15.0000	0.00	3.45	6.92	10.50	14.10	17.62	21.03	24.19	26.56	28.03
57	15.0000	0.00	1.74	3.74	3.53	7.30	9.21	11.31	13.76	16.97	20.69
58	16.0000	10	0								
59	16.0000	0.00	1.91	4.79	8.33	11.91	15.45	18.94	22.25	25.02	26.88
60	16.0000	0.00	2.98	5.59	7.26	8.67	10.58	12.38	14.47	17.25	20.69
61	17.0000	10	0								
62	17.0000	0.00	2.43	5.41	8.56	11.72	14.84	17.93	20.96	23.57	25.28
63	17.0000	5.46	7.75	9.30	10.48	11.65	12.91	14.25	15.71	17.81	20.69
64	18.0000	10	0								
65	18.0000	0.00	2.76	5.63	8.29	11.05	13.79	16.51	19.13	21.51	23.21
66	18.0000	11.61	12.28	12.91	13.55	14.25	15.00	15.62	16.90	18.44	20.69
67	19.0000	10	0								
68	19.0000	0.00	2.37	4.74	7.10	9.46	11.81	14.15	16.44	18.55	20.32
69	19.0000	15.71	15.92	16.10	16.33	16.62	16.97	17.40	18.04	19.11	20.69
70	19.7500	10	0								
71	19.7500	0.00	1.97	3.95	5.92	7.89	9.86	11.82	13.77	15.63	17.22
72	19.7500	17.72	17.82	17.92	18.02	18.14	18.30	18.52	18.38	19.54	20.69
73	20.0000	0	0								
74	20.0000	0.00									
75	20.0000	0.00									
76	82.04	312.09	184.36	218.46	338.79	404.76	396.38	604.66			
77	630.61	526.37	628.94	515.78	553.75	543.42	487.49	968.51			
78	518.97	392.2	237.12	233.9	195.62	24.77	0.				
79	10.5										
80	1										
81	6	7.4584	13.1180	3.0000							
82	8.000	22.58	9.90	45.00000							
83	9.0000	23.20	7.12	45.0000							
84	10.0000	23.65	6.32	45.0000							
85	11.0000	23.04	6.06	45.0000							
86	12.0000	22.56	6.56	45.0000							
87	13.0000	21.44	7.28	45.0000							
88	1										
89	13.5000	16.5000	20.00000	0.0000	0.0000	0.0000	20.5000				

TABLE 11 (CONTINUED)

INPUT CARDS

```
                                          COLUMN
              1         2         3         4         5         6         7         8
CARD 12345678901234567890123456789012345678901234567890123456789012345678901234567890
 90       1
 91  19.2629   19.9022   10.1667   15.0625   15.0625
 92  19.4220   19.7600   10.1667   1.6458    1.6458
 93       1
 94  18.5425   13.6764   18.16     13.6      17.68
 95  18.5425   18.6764   13.52     3.68      3.68
 96  18.5425   18.6764   3.04      13.92     14.4
 97       0
 98       0
 99       0    0
100       1     2.0      SIGNIFICANT
101  10.
102  STOP
```

TABLE 12 - EXAMPLE OF INPUT CARD DESCRIPTION FOR DATA CARD SET 2 FOR LOADS

DATA CARD SET 2 - PROGRAM OPTIONS

OPTION	VLACPR	RAOPR	RLOMPR	LRAOPR
2	0	0	0	1

TABLE 13 - EXAMPLE OF INPUT CARD DESCRIPTION FOR DATA CARD SET 6 FOR LOADS

DATA CARD SET 6 - HULL LINES - LEWIS FORM OR OFFSETS

NO. OF STATIONS = 23   NLOADS = 1

STATION	NLEWF	BEAM	DRAFT	SECARE	DBLWL
0.0000	LINES	0.0000	0.0000	0.0000	
.2500	LINES	17.8400	30.2700	.3782	
1.0000	LINES	16.3800	29.4500	.5355	
2.0000	LINES	20.6200	25.3900	.4902	
3.0000	LINES	31.2000	20.6900	.5965	
4.0000	LINES	40.4200	20.6900	.6238	
5.0000	LINES	47.4400	20.6900	.6623	
6.0000	LINES	52.2200	20.6900	.7063	
7.0000	LINES	55.3800	20.6900	.7490	
8.0000	LINES	57.3800	20.6900	.7854	
9.0000	LINES	58.4600	20.6900	.8131	
10.0000	LINES	58.9200	20.6900	.8284	
11.0000	LINES	58.9800	20.6900	.8274	
12.0000	LINES	58.8200	20.6900	.8052	
13.0000	LINES	58.4200	20.6900	.7623	
14.0000	LINES	57.5400	20.6900	.7022	
15.0000	LINES	56.0800	20.6900	.6226	
16.0000	LINES	53.7800	20.6900	.5237	
17.0000	LINES	50.5600	15.2100	.5550	
18.0000	LINES	46.4200	9.0800	.6540	
19.0000	LINES	40.6400	4.9800	.7283	
19.7500	LINES	34.4400	2.9700	.7612	
20.0000	LINES	0.0000	0.0000	0.0000	

STATION	NOFFSET	NLEWF		OFFSETS- Y=HALF BREADTH, Z=WATERLINE (FROM KEEL)										
0.0000	1	LINES	Y=	0.00										
0.0000	1	LINES	Z=	0.00										
.2500	10	LINES	Y=	0.00	4.45	8.17	8.82	5.87	2.04	.48	.48	.69	1.18
.2500	10	LINES	Z=	-9.58	-9.04	-6.63	-2.37	.83	3.18	7.22	11.72	16.21	20.69
1.0000	10	LINES	Y=	0.00	4.25	7.95	8.19	4.99	2.27	2.27	2.83	3.66	4.74
1.0000	10	LINES	Z=	-8.76	-8.26	-6.20	-2.25	.58	3.82	8.07	12.33	16.54	20.69
2.0000	10	LINES	Y=	0.00	1.48	1.12	2.75	4.09	5.35	6.61	7.84	9.07	10.31
2.0000	10	LINES	Z=	-4.70	-2.95	.07	2.85	5.79	8.76	11.73	14.72	17.71	20.69
3.0000	10	LINES	Y=	0.00	2.84	4.57	6.40	8.12	9.78	11.36	12.83	14.24	15.60
3.0000	10	LINES	Z=	0.00	1.19	3.31	5.63	8.02	10.45	12.94	15.43	18.08	20.69
4.0000	10	LINES	Y=	0.00	3.09	5.78	8.32	10.69	12.90	14.96	16.88	18.61	20.21
4.0000	10	LINES	Z=	0.00	.97	2.87	4.98	7.27	9.72	12.31	15.00	17.80	20.69

TABLE 13 (CONTINUED)

5.0000	10	LINES	Y=	0.00	3.54	6.81	9.92	12.83	15.51	17.96	20.14	22.05	23.72
5.0000	10	LINES	Z=	0.00	.70	2.27	4.15	6.33	8.78	11.46	14.37	17.47	20.69
6.0000	10	LINES	Y=	0.00	2.88	7.62	11.19	14.53	17.57	20.25	22.54	24.47	23.11
6.0000	10	LINES	Z=	0.00	.44	1.60	3.20	5.24	7.70	10.56	13.73	17.13	20.69
				.			.			.			
				.			.			.			
				.			.			.			
19.0000	10	LINES	Y=	0.00	2.37	4.74	7.10	9.46	11.81	14.15	16.44	18.55	20.32
19.0000	10	LINES	Z=	15.71	15.92	16.10	16.33	16.62	16.97	17.40	18.04	19.11	20.69
19.7500	10	LINES	Y=	0.00	1.97	3.95	5.92	7.89	9.86	11.83	13.77	15.63	17.22
19.7500	10	LINES	Z=	17.72	17.82	17.92	18.02	18.14	18.30	18.52	18.88	19.54	20.69
20.0000	1	LINES	Y=	0.00									
20.0000	1	LINES	Z=	0.00									

WEIGHT CURVE

STATION	WEIGHT
0.0000	82.0400
.2500	312.0900
1.0000	184.3600
2.0000	218.4600
3.0000	333.7900
4.0000	404.7500
5.0000	396.3500
6.0000	604.5500
7.0000	630.6100
8.0000	526.3700
9.0000	528.9400
10.0000	515.7500
11.0000	552.7500
12.0000	543.4200
13.0000	487.4900
14.0000	568.5100
15.0000	516.9700
16.0000	382.2000
17.0000	237.1200
18.0000	233.9000
19.0000	195.8200
19.7500	24.7700
20.0000	0.0000

LOAD STATIONS-

10.5000

TABLE 14 - EXAMPLE OF LOAD RESPONSE AMPLITUDE OPERATORS AND PHASES FOR DDG-51

HD.DAT DDG5' BY JWK 7/19/83 DRAFT - 20.69 FT TRIM - 0.00 FT

LOAD RESPONSE AMPLITUDE OPERATORS (RAOS) AND PHASES

STATION 10.8

SHIP SPEED = 15. KNOTS
SHIP HEADING = 45. DEGREES

		V.SHEAR(V3)		V.MOM.(V5)	
OMEGA RPS	OMEGAE RPS	AMPL. TONS	PHASE DEG	AMPL. FT-TONS	PHASE DEG
.200	.222	1.8279E-01	149.2	1.1114E+04	-25.8
.250	.285	5.0340E-01	161.4	1.4317E+04	-38.9
.300	.350	1.1806E+00	171.4	1.5860E+04	-72.2
.350	.418	2.6162E+00	-177.9	4.0932E+04	-118.7
.400	.469	5.5883E+00	-166.8	1.7434E+05	-144.6
.425	.526	8.0661E+00	-161.1	3.3174E+05	-151.8
.450	.563	1.1582E+01	-155.5	5.8608E+05	-157.2
.475	.601	1.6590E+01	-150.0	9.6564E+05	-161.5
.500	.639	2.3734E+01	-144.8	1.4918E+06	-165.1
.525	.678	3.3903E+01	-139.8	2.1690E+06	-168.2
.550	.718	4.8264E+01	-135.4	2.9718E+06	-171.0
.575	.759	6.8220E+01	-131.6	3.8329E+06	-173.5
.600	.800	9.5176E+01	-128.5	4.6376E+06	-175.6
.650	.886	1.71[illegible]E+02	-124.8	5.5138E+06	-176.9
.700	.973	2.82[illegible]E+02	-123.6	5.3561E+06	-168.1
.750	1.063	2.7756E+02	-119.1	7.8879E+06	-148.2
.800	1.156	3.1735E+02	-103.2	1.6783E+07	-143.6
.850	1.252	5.3150E+02	-91.1	2.4507E+07	-150.0
.900	1.351	7.8007E+02	-87.9	2.5399E+07	-1[illegible]3.7
.950	1.453	9.1793E+02	-86.2	2.0869E+07	-162.5
1.000	1.557	9.1973E+02	-84.0	1.3450E+07	-165.4
1.100	1.774	5.6891E+02	-76.9	1.5291E+06	174.9
1.200	2.002	1.5251E+02	-52.3	6.0685E+05	25.1
1.300	2.241	6.4346E+01	21.4	1.9596E+05	22.6
1.400	2.491	1.1302E+02	75.9	1.3307E+06	26.4
1.600	3.025	8.9991E+01	56.1	1.6261E+06	-133.1
1.800	3.604	5.0114E+00	78.8	2.3195E+06	28.0
2.000	4.227	1.0696E+02	.5	2.5114E+06	176.5
2.200	4.995	1.0359E+02	105.1	3.0950E+06	-71.2
2.400	5.607	1.0023E+02	-148.7	3.8887E+06	30.2

NOTE: HEADING CONVENTION: 0 DEG=HEAD, 90 DEG= STBD BEAM, 180 DEG= FOLLOWING SEAS.

TABLE 15 - EXAMPLE OF PSV/TOE TABLE FOR VERTICAL SHEAR FORCE FOR DDG-51

HD.DAT DDG51 BY JWK 7/19/83 DRAFT - 20.69 FT TRIM - 0.00 FT

SHORTCRESTED
SIGNIFICANT WAVE HEIGHT = 10.00 FEET

STATION 10.5

V.SHEAR FORCE
(TONS)

(FORCE / 100)

SIGNIFICANT VALUE / ENCOUNTERED MODAL PERIOD (TOE)

V	TO	HEAD 0	15	30	45	60	75	STBD BEAM 90	105	120	135	150	165	FOLLOW 180
		SHIP HEADING ANGLE IN DEGREES												
0	9	1.81/ 7	1.47/ 7	1.37/ 7	1.23/ 7	1.07/ 7	.95/ 7	.91/ 7	.99/ 7	1.14/ 7	1.31/ 7	1.45/ 7	1.55/ 8	1.60/ 8
	11	1.23/ 8	1.20/ 8	1.12/ 8	.99/ 7	.85/ 7	.74/ 7	.71/ 7	.79/ 7	.93/ 8	1.08/ 8	1.21/ 8	1.30/ 8	1.33/ 8
	13	.97/ 8	.95/ 8	.88/ 8	.78/ 8	.66/ 7	.57/ 7	.53/ 7	.61/ 8	.73/ 8	.85/ 8	.95/ 8	1.03/ 8	1.06/ 8
	15	.77/ 8	.75/ 8	.69/ 8	.61/ 8	.52/ 8	.45/ 7	.43/ 7	.48/ 8	.57/ 8	.68/ 8	.76/ 8	.82/ 8	.84/ 8
	17	.61/ 8	.60/ 8	.55/ 8	.49/ 8	.41/ 8	.36/ 7	.34/ 7	.38/ 8	.46/ 8	.54/ 8	.61/ 8	.66/ 8	.68/ 8
15	9	1.29/ 5	1.26/ 5	1.17/ 5	1.06/ 5	1.00/10	1.08/14	1.27/14	1.55/14	1.85/14	2.12/14	2.33/20	2.47/20	2.52/20
	11	1.10/ 5	1.08/ 5	1.00/ 5	.89/ 5	.81/10	.82/14	.96/14	1.16/14	1.39/14	1.60/17	1.77/20	1.88/20	1.92/20
	13	.89/ 5	.87/ 5	.81/ 5	.72/ 6	.65/10	.64/14	.73/14	.88/14	1.06/17	1.22/17	1.36/20	1.44/20	1.47/20
	15	.72/ 6	.70/ 6	.65/ 6	.58/ 6	.51/10	.50/14	.57/14	.69/14	.82/17	.95/20	1.06/20	1.12/20	1.15/20
	17	.58/ 6	.57/ 6	.53/ 6	.47/ 6	.42/10	.40/14	.45/14	.54/14	.65/17	.76/20	.84/20	.89/20	.91/20

TABLE 16 - EXAMPLE OF RSV/TOE TABLE FOR VERTICAL BENDING MOMENT FOR DDG-51

HD.DAT DDG51 BY JMK 7/19/83 DRAFT - 20.69 FT TRIM - 0.00 FT

SHORTCRESTED
SIGNIFICANT WAVE HEIGHT - 10.00 FEET

STATION 10.5

V.BEND. MOMENT
(FT-TONS)

(MOMENT / 10000)

SIGNIFICANT VALUE / ENCOUNTERED MODAL PERIOD (TOE)

V	TO	HEAD 0	15	30	45	60	75	STBD BEAM 90	105	120	135	150	165	FOLLOW 180
0	9	2.64/ 8	2.58/ 8	2.43/ 8	2.24/ 8	2.08/ 8	2.02/ 8	2.08/ 8	2.24/ 8	2.44/ 8	2.64/ 8	2.78/ 8	2.87/ 8	2.90/ 8
	11	2.52/ 9	2.47/ 9	2.30/ 9	2.08/ 9	1.88/ 9	1.73/ 8	1.75/ 8	1.91/ 8	2.16/ 9	2.40/ 9	2.61/ 9	2.73/ 9	2.78/ 9
	13	2.19/10	2.14/10	1.99/10	1.78/10	1.56/10	1.42/ 9	1.42/ 9	1.57/ 9	1.80/ 9	2.04/ 9	2.23/10	2.36/10	2.40/10
	15	1.84/10	1.79/10	1.67/10	1.48/10	1.29/10	1.16/ 9	1.15/ 9	1.27/ 9	1.47/10	1.68/10	1.86/10	1.97/10	2.01/10
	17	1.53/10	1.50/10	1.39/10	1.23/10	1.07/10	.95/10	.94/ 9	1.04/ 9	1.21/10	1.39/10	1.54/10	1.64/10	1.67/10
15	9	1.86/ 5	1.82/ 5	1.72/ 5	1.64/ 5	1.62/10	1.71/14	1.89/14	2.13/14	2.36/17	2.54/17	2.68/17	2.76/17	2.78/17
	11	1.77/ 5	1.73/ 5	1.63/ 5	1.49/ 5	1.40/ 7	1.42/14	1.57/14	1.80/17	2.06/17	2.29/17	2.47/17	2.59/17	2.63/17
	13	1.55/ 8	1.51/ 8	1.41/ 8	1.28/ 8	1.17/ 7	1.18/14	1.27/14	1.47/17	1.71/17	1.93/17	2.11/20	2.22/20	2.26/20
	15	1.31/ 8	1.28/ 8	1.19/ 8	1.07/ 8	.97/10	.94/14	1.02/17	1.19/17	1.40/17	1.60/20	1.75/20	1.86/20	1.89/20
	17	1.10/ 8	1.07/ 8	1.00/ 8	.90/ 8	.80/10	.77/14	.84/17	.98/17	1.15/17	1.32/20	1.45/20	1.54/20	1.57/20

SHIP HEADING ANGLE IN DEGREES

TABLE 17 - DETERMINATION OF MODAL WAVE PERIODS AS A FUNCTION OF SIGNIFICANT WAVE HEIGHT FOR THE SEVERE MOTION TABLES

Significant Wave Height meters			Modal Wave Period seconds
0		1.26	5
1.26	-	2.24	7
2.24	-	3.97	9
3.97	-	6.34	11
6.34	-	12.29	15
	>	12.29	17 or 19*

*Selection depends on the range of modal wave periods used in SMP:
3-17 seconds for ships with roll periods $\leq$ 15 seconds
7-21 seconds for ships with roll periods $\geq$ 15 seconds

TABLE 18 - EXAMPLE OF SEVERE MOTION TABLE FOR USCGC BEAR

UNITED STATES COAST GUARD 270-FT WMEC FULL-SCALE SIMULATION (STERN TRIM - 3/84)

S E V E R E   M O T I O N   T A B L E

SHORTCRESTED

SEA STATE: SIGNIFICANT WAVE HEIGHT = 13.00 FEET
MODAL WAVE PERIOD = 9. SECONDS

		POINT LOCATIONS:		
P1-	CREWS MESS	XFP = 11.45	YCL = -17.80	ZBL = 28.30
P2-	CSC/PILOTHOUSE	XFP = 5.50	YCL = 4.25	ZBL = 48.30
P3-	HELICOPTER FLIGHT DECK	XFP = 13.88	YCL = -3.40	ZBL = 29.70
P4-	COMMUNICATIONS CENTER	XFP = 4.24	YCL = 4.90	ZBL = 14.30

SIGNIFICANT VALUE / ENCOUNTERED MODAL PERIOD (TOE)

MAXIMUM RESPONSES AND CONDITIONS

RESPONSE	HEAVE	PITCH	SWAY	ROLL	YAW	P1VAC	P1LAC	P2VAC	P2LAC	P3VAC	P3LAC	P4VAC	P4LAC
(MAX.RSV)/TOE	6.33/ 5	4.53/ 4	5.71/19	9.90/13	3.13/17	29.02/ 4	9.83/ 8	49.11/ 4	13.69/10	30.24/ 4	10.61/ 8	55.38/ 4	10.04/ 8
AT SPEED (KNOTS)	20.0	20.0	20.0	20.0	15.0	20.0	0.0	20.0	0.0	20.0	0.0	20.0	20.0
AT HEADING (DEG)	45.	0.	135.	120.	180.	15.	90.	0.	90.	0.	90.	0.	75.

ASSOCIATED RESPONSES

MAX. RESPN.	SPEED / HEADING	HEAVE	PITCH	SWAY	ROLL	YAW	P1VAC	P1LAC	P2VAC	P2LAC	P3VAC	P3LAC	P4VAC	P4LAC
HEAVE	20/ 45	6.33/ 5	3.98/ 4	2.71/13	3.74/13	.88/13	28.12/ 4	6.30/ 6	44.18/ 4	10.71/ 6	28.68/ 4	8.95/ 6	49.48/ 4	8.99/ 6
PITCH	20/ 0	6.13/ 5	4.53/ 4	1.22/ 7	1.03/ 8	.54/ 6	28.96/ 4	5.23/ 6	49.11/ 4	6.69/ 6	30.24/ 4	5.98/ 5	55.38/ 4	6.17/ 5
SWAY	20/135	4.37/19	2.58/13	5.71/19	9.55/13	2.89/13	10.13/12	6.25/13	10.72/ 4	7.72/13	9.10/ 4	6.75/12	11.44/ 4	5.94/13
ROLL	20/120	4.94/19	2.36/13	5.69/19	9.90/13	2.82/13	14.09/13	7.75/13	18.53/ 4	9.71/13	13.14/ 4	8.29/13	17.88/ 4	7.56/13
YAW	15/180	3.42/17	2.79/17	3.49/17	7.51/14	3.13/17	2.72/14	2.83/14	2.92/14	2.88/10	2.23/17	3.66/14	3.25/14	2.83/14
P1VAC	20/ 15	6.17/ 5	4.46/ 4	1.44/ 7	1.28/ 9	.56/ 6	29.02/ 4	5.79/ 6	48.81/ 4	7.44/ 6	30.18/ 4	6.49/ 5	54.77/ 4	6.69/ 5
P1LAC	0/ 90	5.33/ 9	2.93/ 8	3.67/11	9.34/10	1.38/ 5	14.42/10	9.83/ 5	17.02/ 6	13.69/10	13.73/ 7	10.61/ 8	18.87/ 6	9.88/ 7
P2VAC	20/ 0	6.13/ 5	4.53/ 4	1.22/ 7	1.03/ 8	.54/ 6	28.96/ 4	5.23/ 6	49.11/ 4	6.69/ 6	30.24/ 4	5.98/ 5	55.38/ 4	6.17/ 5
P2LAC	0/ 90	5.33/ 9	2.93/ 8	3.67/11	9.34/10	1.38/ 8	14.42/10	9.83/ 8	17.02/ 6	13.69/10	13.73/ 7	10.61/ 8	18.87/ 6	9.88/ 7

TABLE 18 (CONTINUED)

P3VAC	20/ 0	6.13/ 5	4.53/ 4	1.22/ 7	1.03/ 8	.54/ 6	28.96/ 4	5.23/ 6	49.11/ 4	6.69/ 6	30.24/ 4	5.98/ 5	58.38/ 4	6.17/ 8
P3LAC	0/ 90	5.33/ 9	2.93/ 8	3.67/11	9.34/10	1.38/ 9	14.42/10	9.83/ 8	17.02/ 8	13.69/10	13.73/ 7	10.61/ 8	18.87/ 6	9.58/ 7
P4VAC	20/ 0	6.13/ 5	4.53/ 4	1.22/ 7	1.03/ 8	.54/ 6	28.96/ 4	5.23/ 6	49.11/ 4	6.69/ 6	30.24/ 4	5.98/ 5	58.33/ 4	6.17/ 8
P4LAC	20/ 75	6.18/13	3.24/13	4.27/13	7.43/13	1.81/13	24.54/ 4	9.67/ 8	35.14/ 4	12.39/ 6	24.36/ 4	10.33/13	38.97/ 4	10.04/ 6

NOTES: 1) RESPONSES ARE IN PHYSICAL UNITS:
HEAVE AND SWAY ARE IN WAVE HEIGHT UNITS: PITCH, ROLL, AND YAW ARE IN DEGREES;
AND THE POINT VERTICAL AND LATERAL ACCELERATIONS ARE IN UNITS OF G-S * 100.
2) POINT LOCATIONS: XFP IS IN STATION NUMBERS; YCL AND ZBL ARE IN WAVE HEIGHT UNITS.
3) HEADING CONVENTION: 0 DEG=HEAD, 90 DEG=STBD BEAM, 180 DEG=FOLLOWING SEAS.

TABLE 19 - LISTING OF SMP84 SEGMENTATION CARDS

```
      TREE SMP81-(INPUT-(READ,HSTAT,HSTOUT),REGWAV-(HYDCAL-(HYD2D,T3DAMD,
,COFOUT),RDBASE,EQMOTN),IRGSEA,OUTPUT-(RAOOUT,LRAOUT,RMSOUT))
SMP81 INCLUDE SMP81
INPUT INCLUDE INPUT
READ INCLUDE READ,AINPUT,GENOFS,BRWVSP,BMAX,SPLNAR,SPLNT2,SPINT2,PRELIM,
,CUBCO2
HSTAT INCLUDE HSTAT,SPINTG,SPLVAL,SPFIT,SPLNT2,CUBCO2,NORMAL,VUNIT2,CONI
,WT,PDER,PADD,RSOLVE,SPINT2,SPPLV2,NORNTS,RDCOMP,PMPY,PVAL,PINT,TRIM,SPL
,NFT
HSTOUT INCLUDE HSTOUT
REGWAV INCLUDE REGWAV
HYDCAL INCLUDE HYDCAL
HYD2D INCLUDE HYD2D,TWODPT,GRNLOG,GRNFRQ,ALAG,EXPINT,CPFIT,WTPELM,CDCOMP
,,CSOLVE,ATAN3
T3DAMD INCLUDE T3DAMD,RPHI2D,T2DAMD,CPFIT,AMUPRN,SPFIT,SPINTG,CPLVAL,SPL
,VAL
COFOUT INCLUDE COFOUT,FINTSP,AMD,RDPELM,EXFOR,CPFIT,CPINTG,CPLVAL
RDBASE INCLUDE RDBASE,RDPRIM,WAVMAK,HLLIFT,RDLIFT,SKLIFT,BKLIFT,FNLIFT,S
,KNFRC,RDEDDY,HLEDDY,BKEDDY,FNEDDY,SKFRSP,EDMKSP,REVAL,CEVAL,SECT,TANAKA
,,VISC,SERAB,SERD,SERE,FTWO,FIG56,FIG7,FIG8,FIG10,FIG11,CALRGM,BILGEK,BM
,AX,CHINR,FINTSP,SBEDDY,SBLIFT,SPFIT,CPLVAL,CPFIY
EQMOTN INCLUDE EQMOTN,LIMIT,SOLVE,CLIP,TRNLAT,RUEVAL,RVSLAT,LSCOF,REVAL,
,INERST,CSOLVE,CDCOMP,EDMKSP,SKFRSP,FINTSP,ACTFIN
IRGSEA INCLUDE IRGSEA,RMSTOE,WEDEFN,RAOPHS,PRAO,ADRES,ATAN2D,ORAO,VELACC
,,RAOPHA,RELMOT,RMS,TOE,PSPSC,ALGRNG,SCB2,XMSSC,PSPLC,INTRPL,TEPEAK,
,FNRAO,LRAO,CPFIT,CPLVAL,CPINTG
OUTPUT INCLUDE OUTPUT,RSTITL
RAOOUT INCLUDE RAOOUT,RLITR,ORGRAO,TFNFIT,RAOPHA,ATAN2D,CPFIT,CPLVAL,SPF
,IT,SPLVAL,ALGRNG
LRAOUT INCLUDE LRAOUT,LRAO,RAOPHA,ATAN2D,CPFIT,CPLVAL,CPINTG
RMSOUT INCLUDE RMSOUT,RLITER,FETCH,SPLVAL,SPFIT,DKWSLM,RLITR,SETSEV,
,SEVMUT
HYDCAL GLOBAL STELEM
       GLOBAL DATINP,IO,PHYSCO,ENVIOR,RESPN,STATE,GEOM,APPEND,CH3D,INDEX
       GLOBAL FINCON,LOADS
        END
```

APPENDIX A
LISTING OF UPDATES TO SMP SOURCE CODE

```
*ID SMP84
*D DATINP.3
     2 LRAOPR,GMNOM,KG,STATN(25),NSOFST(25),
*D IO.3
     2 ISCARD,BLKFIL,SCRFIL,SPLFIL,LCOFIL,LRAFIL,SEVFIL
*D IO.5
     2 ISCARD,BLKFIL,SCRFIL,SPLFIL,LCOFIL,LRAFIL,SEVFIL
*D INDEX.2,4
       COMMON /INDEX/ PFIDX,LPFIDX,RMIDX,LRMIDX,SVIDX,LSVIDX
       INTEGER LPFIDX,LRMIDX,LSVIDX
       REAL PFIDX(235),RMIDX(183),SVIDX(3)
*D RESPN.2,3
       COMMON /RESPN/ NRESP,IPOINT(182),IMOTN(182),ITYPE(182),
     2 ILIN(182),ISYM(182)
*D RDGEO.3
     2 BKT(25),RKS(25),SSTR(25)
*D SMP81.3
     2 TAPE3,TAPE4,TAPE10,TAPE11,TAPE12,TAPE13,TAPE14,TAPE15)
*I PRELIM.19
       LCOFIL = 4
       LRAFIL = 10
*I PRELIM.22
       SEVFIL = 14
*I READ.11
*CA LOADS
*CA FINCON
*D READ.43,45
       READ  (ICARD,1025) OPTN,VLACPR,RAOPR,RLDMPR,LRAOPR
       WRITE (IPRIN,1030) OPTN,VLACPR,RAOPR,RLDMPR,LRAOPR
 1025  FORMAT (16I5)
*D READ.47
     2 4X,6HVLACPR,5X,5HRAOPR,4X,6HRLDMPR,4X,6HLRAOPR/5I10)
*I READ.63
C    SPEED DEFINITION
       IF (PUNITS(1) .NE. METER) VKMETR = VKMETR/FTMEYR
       METRVK = 1./VKMETR
       CON = VKMETR/SQRT(GRAV*LPP)
       IF (VKINC .EQ. 0.) VKINC = 5.
       IV = 0
    5  IV = IV + 1
       VK(IV) = (IV-1)*VKINC
       VFS(IV) = VKMETR*VK(IV)
       FRNUM(IV) = CON*VK(IV)
       IF (VK(IV) .LT. VKDES .AND. IV .LT. 6) GO TO 5
       NVK = IV
       FNDES = CON*VKDES

*D READ.67
 1080  FORMAT (8F10.4)
*D READ.73,74
       READ  (ICARD,1020) NSTATN,NLOADS
       WRITE (IPRIN,1100) NSTATN,NLOADS
*D READ.77,78
     2 7HOFFSETS//19H  NO. OF STATIONS =,I3,4X,8HNLOADS =,I3//
     2 3X,7HSTATION,5X,5HNLEWF,6X,4HBEAM,5X,5HDRAFT,4X,6HSECARE,
     2 5X,5HDBLWL/)
*I READ.136
       IF (NLOADS .EQ. 0) GO TO 85
C    READ WEIGHT CURVE
       READ  (ICARD,1080) (SWGHT(K),K=1,NSTATN)
       WRITE (IPRIN,1333)
 1333  FORMAT (//7X,12HWEIGHT CURVE//3X,7HSTATION,4X,6HWEIGHT/)
```

```
      DO 157 K=1,NSTATN
      WRITE (IPRIN,1080) STATN(K),SWGHT(K)
  157 CONTINUE
C     READ LOCATIONS (STATIONS) WHERE LOADS ARE TO BE CALCULATED
      READ  (ICARD,1080) (XLDSTN(K),K=1,NLOADS)
      WRITE (IPRIN,1336)
 1336 FORMAT (//4X,14HLOAD STATIONS-/)
      WRITE (IPRIN,1080) (XLDSTN(K),K=1,NLOADS)
   85 CONTINUE
*D READ.242,245
      READ  (ICARD,1020) NFNSET,IACTFN,IFCLCS
      WRITE (IPRIN,1230) NFNSET,IACTFN,IFCLCS
 1230 FORMAT ( ///36H  DATA CARD SET 11 - FIN PARTICULARS//
     2 4X,6HNFNSET,4X,6HIACTFN,4X,6HIFCLCS/3I10)
*I READ.246
      IF (IACTFN .EQ. 0) GO TO 132
      READ  (ICARD,1080) (FGAIN(IV),IV=1,NVK)
      WRITE (IPRIN,2010) (VK(IV),IV=1,NVK)
 2010 FORMAT ( /22H  SHIP SPEED (KNOTS) =,8F10.3)
      WRITE (IPRIN,2020) (FGAIN(IV),IV=1,NVK)
 2020 FORMAT (  22H  FIN GAIN FACTORS    =,8F10.3)
      READ  (ICARD,1080) FK
      WRITE (IPRIN,2030) FK
 2030 FORMAT (//22H  CONTROLLER COEFF.   =,3F10.3)
      READ  (ICARD,1080) FA
      WRITE (IPRIN,2040) FA
 2040 FORMAT ( /22H  SERVO COEFFICIENTS =,3F10.3)
      READ  (ICARD,1080) FB
      WRITE (IPRIN,2050) FB
 2050 FORMAT ( /22H  COMPENSATION COEFF.=,3F10.3)
  132 IF (IFCLCS .EQ. 0) GO TO 136
      WRITE (IPRIN,2060)
 2060 FORMAT (//39X,30HCORRECTED FIN LIFT CURVE SLOPE)
      WRITE (IPRIN,2010) (VK(IV),IV=1,NVK)
      WRITE (IPRIN,1177)
      DO 134 K=1,NFNSET
      READ  (ICARD,1080) (FCLCS(IV,K),IV=1,NVK)
      WRITE (IPRIN,2070) K,(FCLCS(IV,K),IV=1,NVK)
 2070 FORMAT (7H  FNSET,I2,13H  -  FCLCS  =,8F10.3)
  134 CONTINUE
  136 CONTINUE
*D READ.260
      FNIMAG(K) = 1.
      IF (FNRHB(K) .NE. 0.) FNIMAG(K) = 2.
*D READ.430,442
*I READ.511
C           1*2 =  2 FINS
*D READ.518
C     ROLL
      L = 1
*D READ.524,525
      IF (.NOT.(VLACPR.GT.0.OR.STATNM(1).EQ.EQVLIN)) GO TO 502
C     ROLL VELOCITY
      L = L + 1
*D READ.531
  502 IF (IACTFN .EQ. 0) GO TO 508
C     FIN & FIN VELOCITY
      M1 = 1
      IF (VLACPR .GT. 0) M1 = 2
      DO 505 IT=1,M1
      L = L + 1
      IPOINT(L) = 0
```

```
      IMOTN(L) = 9
      ITYPE(L) = IT
      ILIN(L) = .FALSE.
      ISYM(L) = .TRUE.
  505 CONTINUE
  508 NRESP = L
      GO TO 580
*I READ.544
      IF (IACTFN .EQ. 0) GO TO 525
C     FIN, FIN VELOCITY, AND FIN ACCELERATION
      DO 522 IT=1,3
      L = L + 1
      IPOINT(L) = 0
      IMOTN(L) = 9
      ITYPE(L) = IT
      ILIN(L) = .FALSE.
      ISYM(L) = .TRUE.
  522 CONTINUE
  525 CONTINUE
*I READ.584
      IF (NLOADS .EQ. 0) GO TO 700
C     LOADS AT SPECIFIED STATIONS
      DO 620 K=1,NLOADS
C     I=10 (H.SHEAR)
C     I=11 (V.SHEAR)
C     I=12 (T.MOM.)
C     I=13 (V.MOM.)
C     I=14 (H.MOM.)
      DO 610 I=10,14
      IF (.NOT. (I.EQ.11.OR.I.EQ.13)) GO TO 610
      L = L + 1
      IPOINT(L) = K
      IMOTN(L) = I
      ITYPE(L) = 1
      ILIN(L) = .TRUE.
      ISYM(L) = .TRUE.
  610 CONTINUE
  620 CONTINUE
  700 CONTINUE
*I READ.590
      IF (NLOADS .GT. 0) LOADS = .TRUE.
*I READ.591
      IF (ISKIP .EQ. 1) ADDRES = .FALSE.
*D READ.602
      LRMIDX = 183
*I READ.603
      LSVIDX = 3
      CALL OPENMS (SEVFIL,SVIDX,LSVIDX,0)
*I HSTAT.22
*CA LOADS
*I HSTAT.28
      REAL METER
      DATA METER /4HMETE/
*I MSTAT.186
      IF (NLOADS .EQ. 0) GO TO 69
C     OBTAIN LOCATIONS FOR LOAD CALCULATIONS
      DO 65 IP=1,NLOADS
      XLS = XLDSTN(IP)
      N1 = NSTATN - 1
      DO 63 K=1,N1
      IF (.NOT. (XLS.GE.STATN(K) .AND. XLS.LT.STATN(K+1))) GO TO 63
      XLDSTN(IP) = 0.5*(STATN(K) + STATN(K+1))
```

```
      GO TO 64
   63 CONTINUE
   64 XLOXPT(IP) = XCB - XLOSTN(IP)*LPP/20
      LSTATN(IP) = NSTATN + 1 - K
   65 CONTINUE
C     COMPUTE SECTION MASS
      L = NSTATN + 1
      DO 68 K=1,NSTATN
      L = L - 1
      IF (PUNITS(1) .EQ. METER) SMASS(L) = SWGHT(K)*1000
      IF (PUNITS(1) .NE. METER) SMASS(L) = SWGHT(K)*2240/GRAV
   68 CONTINUE
   69 CONTINUE
*I HYDCAL.3
*CA STELEM
*D T2DAMD.2
      SUBROUTINE T2DAMD (K,PHI2D,T2D,T3D)
*D T2DAMD.12
      COMPLEX PHI2D(10,10,4),CTEMP,T2D(10,10),T3D(10,10)
*D T2DAMD.30
      CTEMP = (0.,0.)
*D T2DAMD.46
      CTEMP = CTEMP + WTOL(M,K)*NORM(IN,M,K)*PHI2D(ISIGMA,M,JP)
*D T2DAMD.49
      T2D(ISIGMA,L) = 2.0*PI*RHO*SIGMA(ISIGMA)*XFCTR*CTEMP
*D T2DAMD.51
      T3D(ISIGMA,L) = T3D(ISIGMA,L) + WTLI*T2D(ISIGMA,L)
*I T3DAMD.9
*CA STELEM
*I T3DAMD.14
      COMPLEX T2D(10,10)
*D T3DAMD.39
      CALL T2DAMD (K,PHI2D,T2D,T3D)
      M = (K-1)*10
      DO 25 L=LMIN,LMAX
      M = M + 1
      CALL CPFIT (SIGMA,T2D(1,L),STELEM(1,1,M),NSIGMA)
   25 CONTINUE
*I COFOUT.7
*CA GEOM
*I COFOUT.8
*CA STATE
*I COFOUT.12
*CA STELEM
*I COFOUT.14
      COMPLEX STV(3,3),CDUM(3,3),SF3(25),SH3(25)
      DIMENSION SA33(25),SB33(25)
*I COFOUT.31
      IF (OMEGAE .LT. SIGMA(1)) OMEGAE = SIGMA(1)
      WE = OMEGAE
      WE2 = WE*WE
*I COFOUT.32
      DO 50 K=1,NSTATN
      SA33(K) = 0.
      SB33(K) = 0.
      NPT = NOFSET(K)
      IF (NPT .LT. 2) GO TO 50
      M = (K-1)*10 + 1
      CALL AMD (OMEGAE,STELEM(1,1,M),STV,CDUM)
      SA33(K) = REAL(STV(2,2))/(-WE2)
      SB33(K) = AIMAG(STV(2,2))/WE
   50 CONTINUE
```

```
*D COFOUT.33
      CALL AMD (OMEGAE,TELEM,TV,TL)
*D COFOUT.36
      CALL EXFOR (OMEGA(IW),OMEGAE,EXCV,EXCL,HJV,HJL,H7,SF3,SH3)
*I COFOUT.37
      IF (LOADS) WRITE (LCOFIL) (SF3(I),SH3(I),SA33(I),SB33(I),I=1,
     2 NSTATN)
*D AMD.2
      SUBROUTINE AMD (OMEGAE,TELEM,TV,TL)
*D AMD.11
      COMPLEX TELEM(4,9,10)
*D EXFOR.2
      SUBROUTINE EXFOR(OMEGA,OMEGAE,FXV,FXL,HJV,HJL,H7,F3,H3)
*I EXFOR.18
      COMPLEX CEP,F3(25),H3(25),TF3,TH3
*I EXFOR.22
      ARGLI = - WN*COSMU
      IF (ABS(ARGLI) .LE. TEST) ARGLI = 0.
*D EXFOR.33
*I EXFOR.34
      IF (.NOT. LOADS) GO TO 210
      F3(K)=(0.,0.)
      H3(K)=(0.,0.)
  210 CONTINUE
*I EXFOR.55
      IF (.NOT. LOADS) GO TO 220
      TF3=EKZ*NORM3*CARG
      TH3=EKZ*II*TOD*PHI2D(3)
      F3(K)=F3(K)+WTDL(J,K)*TF3
      H3(K)=H3(K)+WTDL(J,K)*TH3
  220 CONTINUE
*D EXFOR.67,69
*D EXFOR.88,90
*I EXFOR.94
      IF (.NOT. LOADS) GO TO 230
C    SECTIONAL FROUDE-KRILOFF "FORCE", F3  W/O CEXP(-II*K*X*COS(MU))
      F3(K)=2*GRAV*F3(K)
C    SECTIONAL DIFFRACTION "FORCE"   . H3  W/O CEXP(-II*K*X*COS(MU))
      H3(K)=2*W*H3(K)
  230 CONTINUE
*D EXFOR.100,101
*D EXFOR.109
*D EXFOR.114,115
*D EXFOR.123
*I EQMOTN.12
*CA FINCON
      COMMON /HULL/ A26
*I EQMOTN.15
      COMPLEX ZERO,TAF(3),CTEMP
      DIMENSION T44T(8)
*I EQMOTN.20
      ZERO = (0.,0.)
*I EQMOTN.48
      WE = OMEGAE(IW)
      WE2 = WE*WE
      A22 = REAL(TL(1,1))/(-WE2)
      B22 = AIMAG(TL(1,1))/WE
      A26V = REAL(TL(1,3))/(-WE2)
      A26 = A26V - (V/WE2)*B22
*D EQMOTN.63,72
      CALL ROEVAL (IV,OMEGA(IW),OMEGAE(IW),NRANG,TLG,EXCLG,TLGC,EXCLGC,
     2 T44T)
```

```
      IF (IACTFN .EQ. 0) GO TO 34
C     ADD ACTIVE FIN COEFFICIENTS
      OMGE  = OMEGAE(IV)
      OMGE2 = OMGE*OMGE
      CALL ACTFIN (IV,ZERO,V,OMGE,OMGE2,TAF)
      DO 32 I=1,3
      TLGC(I,2) = TLGC(I,2) + FGAIN(IV)*TAF(I)
   32 CONTINUE
   34 CTEMP = TLGC(2,2)
C     ADD VISCOUS/BILGEKEEL EDDY DAMPING
      DO 40 IA=1,NRANG
      TLGC(2,2) = CTEMP + II*T44T(IA)
      CALL SOLVE (3,TLGC,EXCLGC,MOTLG,UL,IP,IPRIN)
*D FNLIFT.22
      O = FNIMAG(K)
*I FNLIFT.23
      CR = XRTF - XRTA
      CT = XTPF - XTPA
      XROC = XRTF - 0.25*CR
      XTOC = XTPF - 0.25*CT
      DX = XROC - XTOC
      H = SQRT(DX*DX + SPAN*SPAN)
      COSLAM = SPAN/H
      SECLAM = 1./COSLAM
C     LAM = ACOS(SPAN/H) = QUARTER CHORD SWEEP ANGLE IN RADIANS
*D FNLIFT.40
      LCS = 1.8*PI*EAR/(COSLAM*SQRT((EAR*SECLAM)**2 + 4) + 1.8)
*I RDLIFT.24
      CR = XRTF - XRTA
      CT = XTPF - XTPA
      XROC = XRTF - 0.25*CR
      XTOC = XTPF - 0.25*CT
      DX = XROC - XTOC
      H = SQRT(DX*DX + SPAN*SPAN)
      COSLAM = SPAN/H
      SECLAM = 1./COSLAM
C     LAM = ACOS(SPAN/H) = QUARTER CHORD SWEEP ANGLE IN RADIANS
*D RDLIFT.41
      LCS = 1.8*PI*EAR/(COSLAM*SQRT((EAR*SECLAM)**2 + 4) + 1.8)
*I HLLIFT 2
*CA DATINP
*D HLLIFT.12
      MCHORD = LPP
*D HLLIFT.17
      SS = 0
      SP = 0
      DO 5 L=1,NSTATN
      IF (L .EQ. 1) DX = (X(2) - X(1))/2
      IF (L .EQ. NSTATN) DX = (X(NSTATN) - X(NSTATN-1))/2
      IF (L.GT.1 .AND. L.LT.NSTATN) DX = (X(L+1) - X(L-1))/2
      DX = ABS(DX)
      NPT = NOFSET(L)
      IF (NPT .LT. 2) GO TO 5
      T = ABS(Z(1,L))
      A = T*DX
      SP = SP + A
      SS = SS + X(L)*A
    5 CONTINUE
      XCP = SS/SP
*D HLLIFT.19
      ZCP = 0.
*I LSCOF.6
```

```
      COMMON /HULL/ A26
*I LSCOF.8
      COMPLEX VIW,ZERO,CTEMP
*I LSCOF.10
      LOGICAL HULL
*I LSCOF.12
      ZERO = (0.,0.)
      VIW = V/(II*OMEGAE)
      V2W2 = (V/OMEGAE)**2
*I LSCOF.33
      HULL = .FALSE.
      IF (MCHORD .EQ. LPP) HULL = .TRUE.
      IF (.NOT. HULL) GO TO 52
C     HULL
      DF2 = ZERO
      DF4 = ZERO
      DF6 = ZERO
      SP = 0
      DO 42 L=1,NSTATN
      IF (L .EQ. 1) DX = (X(2) - X(1))/2
      IF (L .EQ. NSTATN) DX = (X(NSTATN) - X(NSTATN-1))/2
      IF (L.GT.1 .AND. L.LT.NSTATN) DX = (X(L+1) - X(L-1))/2
      DX = ABS(DX)
      NPT = NOFSET(L)
      IF (NPT .LT. 2) GO TO 42
      T = ABS(Z(1,L))
      Z2 = Z(1,L)/2
      A = T*DX
      SP = SP + A
      F2 = FZ*OMEGA*(SINGAM*SINMU - II*COSGAM)*
     2 CEXP(CK*(Z2 - II*X(L)*COSMU))
      CTEMP = F2*SINGAM*A
      DF2 = DF2 + CTEMP
      DF6 = DF6 + X(L)*CTEMP + VIW*CTEMP
   42 CONTINUE
      DF2 = DF2/SP
      DF6 = DF6/SP
      CB = NEBLA/(LPP*BEAM*DRAFT)
      CX = AREAMX/(BEAM*DRAFT)
      CP = CB/CX
      GO TO 62
   52 CONTINUE
*I LSCOF 38
   62 CONTINUE
*D LSCOF.60
      IF (.NOT. HULL) DB66 = XCP*XCP*DB22 + V2W2*DB22
      IF (HULL) DB66 = (CP*LPP/2)**2 * DB22 + V*A26 + V2W2*DB22
*D LSCOF 76
      IF (.NOT. HULL) EXCLOC(3) = EXCLG(3) + DF6 + VIW*DF2
      IF (HULL) EXCLOC(3) = EXCLG(3) + DF6
*D RDEVAL 2
      SUBROUTINE RDEVAL (IV,OMEGA,OMEGAE,NRANG,TLG,EXCLG,TLOC,EXCLOC,
     2 T44T)
*D RDEVAL 8
*CA FINCON
      COMPLEX TLG(3,3),EXCLG(3),TLOC(3,3),EXCLOC(3)
      DIMENSION T44T(NRANG)
*D RDEVAL.90
      TEMP = FLCS(K)
      IF (IFCLCS .EQ. 1) TEMP = FCLCS(IV,K)
      CALL LSCOF (OMEGA,OMEGAE,2,FSPAN(K),FMNCHD(K),FAREA(K),TEMP,
*D RDEVAL.94
```

```
    2 CALL LN OF (OMEGA,OMEGAE,2,FSPAN(K),FMNCHD(K),FAREA(K),TEMP,
*D INTRPL.12
      DENOM = XN(KJ) - XN(KL)
      SLOPE = 0.
      IF (DENOM .GT. 0.) SLOPE = (YN(KU) - YN(KL))/DENOM
*D INTRPL.20
      DENOM = XN(KU) - XN(KL)
      SLOPE = 0.
      IF (DENOM .GT. 0.) SLOPE = (YN(KU) - YN(KL))/DENOM
*I RDEVAL.98
      DO 100 IA=1,NRANG
*D RDEVAL.102
*D RDEVAL.122
*I RDEVAL.124
      T44BE = 0.
*D RDEVAL.127
*I RDEVAL.128

      T44T(IA) = T44SFV + T44EMV + T44BE

  100 CONTINUE
*D RMSTOE.25
      DIMENSION XID(911)
*D RMSTOE.28
      NID = 911
*I RMSTOE.49
      REWIND LCOFIL
*I RAOPHS.10
      COMPLEX SF3(25,30),SH3(25,30)
      DIMENSION SA33(25,30),SB33(25,30)
*I RAOPHS.54
      IF (IP.EQ.0 .AND. IM.EQ.9) CALL FNRAO (IV,M1,M2,MOTL(1,1,IA),
    2 RAO1(1,IA),PHS1(1,IA),NMOT,NOMEGA,OMEGAE,IPHS)

*I RAOPHS.62

      IF (.NOT. (IP.GT.0 .AND. (IM.GE.10.AND.IM.LE.14))) GO TO 100
      DO 40 IW=1,NOMEGA
      READ (LCOFIL) (SF3(I,IW),SH3(I,IW),SA33(I,IW),SB33(I,IW),
    2 I=1,NSTATN)
   40 CONTINUE
      CALL LRAO (IM,M1,M2,MOTV,SF3,SH3,SA33,SB33,VFS(IV),COSMU,
    2 OMEGA,OMEGAE,IP,RAO1,PHS1,NMOT,NOMEGA,IPHS)

*I RSTITL.4
*CA LOADS
      DIMENSION LOAD(2,5),LTYPE(3,2),LUNIT(2,3)
      REAL LOAD,LTYPE,LUNIT
*I RSTITL.25
      DATA LOAD /4H H.S,4HHEAR,4H V.S,4HHEAR,4H   T,4HORS.,4H V.B,
    2 4HENC.,4H H.B,4HEND./
      DATA LTYPE /4HFORC,4HE    ,4H    ,4HMOME,4HNT   ,4H    /
      DATA LUNIT /4H   (T,4HONS),4H    ,4H (M-,4HTONS,4H)   ,4H (FT,
    2 4H-TON,4HS)  /
*D RSTITL.101
   50 IF (IM .NE. 9) GO TO 80
C     ANTI-ROLL FINS
      RTITL(1) = 4H
      RTITL(2) = 4H FIN
      IF (IT .EQ. 1) JT = 4
      IF (IT .GT. 1) JT = IT
      DO 60 I=1,3
   60 RTYPE(I) = TYPE(I,JT)
      JT = IT + 3
      DO 70 I=1,3
   70 RUNIT(I) = UNIT(I,JT)
      IF (IT .EQ. 1) FMOT = 3HFIN
      IF (IT .EQ. 2) FMOT = 6HFINVEL
      IF (IT .EQ. 3) FMOT = 6HFINACC
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```
      ENCODE (110,3000,PARS) FMOT,FMOT
   80 IF (.NOT. (IP.GT.O.AND.(IM.GE.10.AND.IM.LE.14))) GO TO 100
C     LOADS
      JM = IM - 9
      RTITL(1) = LOAD(1,JM)
      RTITL(2) = LOAD(2,JM)
      LT = 1
      IF (IM .GT. 11) LT = 2
      MT = LT
      IF (LT.EQ.2.AND.(PUNITS(1).NE.METER)) MT = 3
      DO 82 I=1,3
      RTYPE(I) = LTYPE(I,LT)
      RUNIT(I) = LUNIT(I,MT)
   82 CONTINUE
      IF (JM .EQ. 1) ENCODE (110,3031,PARS) PT(IP),XLOSTN(IP)
      IF (JM .EQ. 2) ENCODE (110,3032,PARS) PT(IP),XLOSTN(IP)
      IF (JM .EQ. 3) ENCODE (110,3033,PARS) PT(IP),XLOSTN(IP)
      IF (JM .EQ. 4) ENCODE (110,3034,PARS) PT(IP),XLOSTN(IP)
      IF (JM .EQ. 5) ENCODE (110,3035,PARS) PT(IP),XLOSTN(IP)
 3031 FORMAT(6HHSHEAR,A3,11X,29HHORIZ.  SHEAR FORCE AT STATION,F8.2,55X)
 3032 FORMAT(6HVSHEAR,A3,11X,29HVERT.   SHEAR FORCE AT STATION,F8.2,55X)
 3033 FORMAT(4HTMOM,  A3,13X,29HTORSIONAL MOMENT    AT STATION,F8.2,53X)
 3034 FORMAT(4HVMOM,  A3,13X,29HVERT.  BEND. MOM.   AT STATION,F8.2,55X)
 3035 FORMAT(4HHMOM,  A3,13X,29HHORIZ. BEND. MOM.   AT STATION,F8.2,55X)
  100 CONTINUE
*I OUTPUT.3
*CA LOADS
*I OUTPUT.4
      IF (NLOADS.GT.O .AND. LRAOPR.GT.O) CALL LRAOUT
*I RMSOUT.9
*CA LOADS
*CA SEVERE
*D RMSOUT.10
      DIMENSION XID(911),YID(182,5),WT(80)
      DIMENSION IMODL(4),LSVRSP(13),RSPNME(2,13)
*D RMSOUT.12
      EQUIVALENCE (IPOINT,YID),(XID,MRESP)
*I RMSOUT.20
      DATA LSVRSP /3,5,2,4,6,9,8,9,8,9,8,9,8/
      DATA RSPNME /4HHEAV,1HE,4HPITC,1HH,4H SWA,1HY,4H ROL,1HL,
     2   4H  YA,1HW,4HP1VA,1HC,4HP1LA,1HC,4HP2VA,1HC,4HP2LA,1HC,
     2   4HP3VA,1HC,4HP3LA,1HC,4HP4VA,1HC,4HP4LA,1HC/
*I RMSOUT.32
      NSVRSP = 13
*D RMSOUT.36
      NID = 911
*I RMSOUT.37
      L = LENGTH(RMSFIL)
      M = (L-1)/5
C     M = 159  MEANS RMSFIL WAS GENERATED BY SMP81
C     M = 182  MEANS RMSFIL WAS GENERATED BY SMP84
      K = 1
      DO 750 J=1,5
      DO 750 I=1,M
      K = K + 1
      YID(I,J) = XID(K)
  750 CONTINUE
      NRESP = MRESP
      DO 770 IS=1,NSIGWH
C     FIND MOST PROBABLE PERIOD
      SWH = SIGWH(IS)
      IF (PUNITS(1) .NE. METER) SWH = SWH*FTMETC
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```
C     SIGNIFICANT WAVE HEIGHT RANGES BELOW ARE IN METERS
C     SEA STATE 1
        IF (SWH .LE. 0.59) PER = 5.0
C     SEA STATE 2
        IF (SWH.GT.0.59 .AND. SWH.LE.1.26) PER = 6.0
C     SEA STATE 3
        IF (SWH.GT.1.26 .AND. SWH.LE.1.73) PER = 7.0
C     SEA STATE 4
        IF (SWH.GT.1.73 .AND. SWH.LE.2.24) PER = 7.0
C     SEA STATE 5
        IF (SWH.GT.2.24 .AND. SWH.LE.3.87) PER = 9.0
C     SEA STATE 6
        IF (SWH.GT.3.87 .AND. SWH.LE.6.34) PER = 11.0
C     SEA STATE 7
        IF (SWH.GT.6.34 .AND. SWH.LE.12.29) PER = 15.0
C     SEA STATE 8
        IF (SWH.GT.12.29 .AND. SWH.LE.18.77) PER = 19.0
C     GREATER THAN SEA STATE 8
        IF (SWH .GT. 18.77) PER = 19.0
        IF (PER .LT. TMODAL(1)) PER = TMODAL(1)
        IF (PER .GT. TMODAL(NTMOD)) PER = TMODAL(NTMOD)
        IMODL(IS) = 1
        DO 760 LT=1,NTMOD
        IF (ABS(PER-TMODAL(LT)) .LT. 0.0001) IMODL(IS) = LT
  760   CONTINUE
  770   CONTINUE
        ISKPSV = 0
        IF (IMOTN(1) .NE. 1) ISKPSV = 1
C     ISKPSV = 0  ALL MOTIONS - OUTPUT SEVERE MOTION TABLES
C     ISKPSV = 1  ROLL MOTION ONLY - SKIP SEVERE MOTION TABLES
        IF (ISKPSV .EQ. 1) GO TO 820
        NSVRSP = 5 + 2*NPTLOC
        IF (NSVRSP .GT. 13) NSVRSP = 13
        CALL SETSEV (NSVRSP,LSVRSP,
        NRSIND = NSVRSP + 1
        NSWIND = NSIGWH + 1
  820   CONTINUE
*I RMSOUT.70
        CALL STINDX (SEVFIL,RSINDX,NRSIND)
        DO 7 I=1,NRSIND
        RSINDX(I) = 0.
    7   CONTINUE
*I RMSOUT.72
        JR = 0
        IF (ISKPSV .EQ. 1) GO TO 19
        DO 18 LR=1,NSVRSP
        IF (IR .NE. LSVRSP(LR)) GO TO 18
        JR = LR
        GO TO 19
   18   CONTINUE
   19   CONTINUE
*I RMSOUT.84
        IF (JR .EQ. 0) GO TO 21
        CALL STINDX (SEVFIL,SWINDX,NSWIND)
        DO 8 I=1,NSWIND
        SWINDX(I) = 0.
    8   CONTINUE
   21   CONTINUE
*I RMSOUT.94
        SWHMAX = .202*TMODAL(ITO)**2
        IF (PUNITS(1) .EQ. METER) SWHMAX = SWHMAX*FTMETR
*D RMSOUT.100,101
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```
*D RMSOUT.148,152
      DO 120 IV=1,NVK
      DO 110 IH=1,NHEAD
      TEMP = RMSTBL(IH,ITO,IV)
      IF (TEMP .LT. RMSMIN) RMSMIN = TEMP
      IF (TEMP .LT. RMSMAX) GO TO 110
      RMSMAX = TEMP
      IF (JR .EQ. 0) GO TO 110
      IF (ITO .NE. IMODL(IS)) GO TO 110
      IF (SYMMET .AND. IH.GT.13) GO TO 110
      MXV = IV
      MXH = IH
  110 CONTINUE
  120 CONTINUE
      IF (JR .EQ. 0) GO TO 150
      IF (ITO .NE. IMODL(IS)) GO TO 150
      RSVTOE(1) = MXV
      RSVTOE(2) = MXH
      IE = 2
      DO 130 IV=1,NVK
      DO 130 IH=1,NHEAD
      IE = IE + 1
      RSVTOE(IE) = RMSTBL(IH,ITO,IV)
      IE = IE + 1
      RSVTOE(IE) = TOETBL(IH,ITO,IV)
  130 CONTINUE

C     WRITE TO SEVERE MOTION FILE
      CALL WRITMS (SEVFIL,RSVTOE,IE,IS)
  150 CONTINUE
*D RMSOUT.197
      IF (IP.GT.0 .AND. IH.LE.3) WRITE (IPRIN,1032) (PTNAME(I,IP),
*I RMSOUT.202
      IF (IP.GT.0 .AND. (IH.GE.10 .AND. IH.LE.14)) WRITE (IPRIN,1073),
     2 XLDSTN(IP)
 1073 FORMAT (/58X,7HSTATION,F5.1)
*I RMSOUT.206
      IF (IP.GT.0 .AND. (IH.GE.10 .AND. IH.LE.11)) WRITE (IPRIN,1083)
 1083 FORMAT (/57X,14H(FORCE / 100 ))
      IF (IP.GT.0 .AND. (IH.GE.12 .AND. IH.LE.14)) WRITE (IPRIN,1088)
 1088 FORMAT (/54X,16H(MOMENT / 10000))
*I RMSOUT.232
      IF (IP.GT.0 .AND. (IH.GE.10 .AND. IH.LE.11)) TEMRMS(IH) =
     2 TEMRMS(IH)/100
      IF (IP.GT.0 .AND. (IH.GE.12 .AND. IH.LE.14)) TEMRMS(IH) =
     2 TEMRMS(IH)/10000
*I RMSOUT.260
      IF (IP.GT.0 .AND. (IH.GE.10 .AND. IH.LE.11)) TEMRMS(IH) =
     2 TEMRMS(IH)/100
      IF (IP.GT.0 .AND. (IH.GE.12 .AND. IH.LE.14)) TEMRMS(IH) =
     2 TEMRMS(IH)/10000
*I RMSOUT.268
      IF (JR .EQ. 0) GO TO 310
      CALL STINDX (SEVFIL,RSINDX,NRSIND)
      CALL WRITMS (SEVFIL,SWINDX,NSWIND,JR)
  310 CONTINUE
*I RMSOUT.272
      IF (ISKPSV .EQ. 1) GO TO 410
      CALL STINDX (SEVFIL,SVIDX,LSVIDX)
      CALL WRITMS (SEVFIL,RSINDX,NRSIND,IC)
  410 CONTINUE
*I RMSOUT.273
```

```
  600  IF (ISKPSV .EQ. 0) CALL SEVMOT (NSVRSP,LSVRSP,RSPNMR,MDNG,IMODL)
*D CALRGM.58,63
C     FIND MINIMUM SLOPE FOR DEADRISE CALCULATION IN "BILGEK"
        M2 = JS - 1
        LS = M2 - 1
        SRB = (Z(M2,K) - Z(LS,K)) / (Y(M2,K) - Y(LS,K))
        J = JS
        DO 130 I=2,M2
        J = J - 1
        JS1 = J - 1
        SLOPE = (Z(J,K) - Z(JS1,K)) / (Y(J,K) - Y(JS1,K))
        IF (SLOPE .EQ. 0.) GO TO 140
        IF (SLOPE .GT. SRB) GO TO 140
        LS= JS1
        SRB = SLOPE
  130  CONTINUE
C     EXTRAPOLATE SLOPE TO CENTERLINE TO GET LOCAL DRAFT
C     (EXCLUDING SKEG OFFSETS)
  140  BKT(K) = Z(LS,K) - SRB*Y(LS,K)
       IF (BKT(K) .LT. Z(1,K)) BKT(K) = Z(1,K)
*D BILGEK.30
       TLOCAL = ABS(BKT(K))
*D SECT.15
       DIMENSION AA(3,4),AR(10)
*I SECT.49
       AR(I) = R
*D SECT.64
       IF (.NOT.(STATN(M).EQ.BKSTN(J,I))) GO TO 20
C     SEARCH FOR MINIMUM RADIUS OF THE BILGE STARTING FROM THE WATERLINE
       RMIN = AR(NNM)
       L = NNODES
       DO 15 NN=2,NNM
       L = L - 1
       R = AR(L)
       IF (R .GT. RMIN) GO TO 1
       RMIN = R
   15  CONTINUE
   17  RDK = RMIN
       ITSK = 4
       GO TO 21
*D WEDEFN.12
       DO 110 I=1,54
*D WEDEFN.14
  110  WEVN(K) = 0.05 + (I-1)*DWE
*D WEDEFN.16
       DO 120 I=1,21
*D WEDEFN.18
  120  WEVN(K) = WEVN(54) + I*DWE
*AF
*COMDECK LOADS
      COMMON /LOADS/ NLOADS,SWGHT(25),SML  S(25),XLDSTN(10),FLDXPT(25),
     2 LSTATN(25)

*COMDECK FINCON
      COMMON /FINCON/ IACTFN,IFCLCS,FGAIN(8),FK(3),FA(3),FB(3),
     2 FCLCS(8,2)

*COMDECK STELEM
      COMMON /STELEM/ STELEM
      COMPLEX STELEM(4,9,250)

*COMDECK SEVERE
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      COMMON /SEVERE/ NRSIND,RSINDX,NSWIND,SWINDX,RSVTOE,RV,RH
      REAL RSINDX(14),SWINDX(5),RSVTOE(403)
      INTEGER RV(13),RH(13)
*DECK ACTFIN
      SUBROUTINE ACTFIN (IV,ZERO,V,OMGE,OMGE2,TAF)
*CA PHYSCO
*CA APPEND
*CA RLDGK
*CA FINCON
      COMPLEX TAF(3),FGC,CTERM,ZERO

      DO 10 I=1,3
      TAF(I) = ZERO
   10 CONTINUE
      FGC = ((FK(1)-OMGE2*FK(3))+II*OMGE*FK(2))/(((FA(1)-OMGE2*FA(3))+
     2 II*OMGE*FA(2))*((FB(1)-OMGE2*FB(3))+II*OMGE*FB(2)))
      DO 30 K=1,NFNSET
      XCP = FXCP(K)
      ARM = - FMNCHD(K)/6
      YHAT = FYHAT(K)
      AP = PI*RHO*FSPAN(K)*(FMNCHD(K)/2)**2
      TEMP = FLCS(K)
      IF (IFCLCS .EQ. 1) TEMP = FCLCS(IV,K)
      FZ = (RHO/2)*FAREA(K)*TEMP
      SINGAM = SIN(FGAMMA(K)*DEGRAD)
      CTERM = FGC*(ARM*AP*OMGE2-II*OMGE*(ARM*FZ-3*AP)*V+FZ*V*V)
      M1 = 1
      IF (FNIMAG(K) .EQ. 2) M1 = 2
C     SIN(180-GAMMA)=SIN(GAMMA)  FOR FIN ON STBD SIDE
      DO 20 M=1,M1
      TAF(1) = TAF(1) - SINGAM*CTERM
      TAF(2) = TAF(2) + YHAT*CTERM
      TAF(3) = TAF(3) - SINGAM*XCP*CTERM
   20 CONTINUE
   30 CONTINUE

      RETURN
      END
*DECK FNRAO
      SUBROUTINE FNRAO (IV,NL,NU,MOTL,RAO,PHS,NMOT,NOMEGA,OMEGAE,IPHS)
*CA PHYSCO
*CA FINCON
      COMPLEX FGC,MOTL(NMOT,NOMEGA),BETA,ROLL
      DIMENSION OMEGAE(NOMEGA),RAO(NOMEGA),PHS(NOMEGA)

      DO 10 I=NL,NU
      ROLL = MOTL(2,I)*RADDEG
      OMGE = OMEGAE(I)
      OMGE2 = OMGE*OMGE
      FGC = ((FK(1)-OMGE2*FK(3))+II*OMGE*FK(2))/(((FA(1)-OMGE2*FA(3))+
     2 II*OMGE*FA(2))*((FB(1)-OMGE2*FB(3))+II*OMGE*FB(2)))
      BETA = FGAIN(IV)*FGC*ROLL
      CALL RAOPHA (BETA,RAO(I),PHS(I),RADDEG,IPHS)
   10 CONTINUE

      RETURN
      END
*DECK LRAO
      SUBROUTINE LRAO (IM,NL,NU,MOTV,SF3,SH3,SA33,SB33,V,COSMU,
     2 OMEGA,OMEGAE,IP,RAO,PHS,NMOT,NOMEGA,IPHS)
*CA DATINP
```

```
*CA PHYSCO
*CA GEOM
*CA LOADS
      COMPLEX MOTV(MOOT,NOMEGA),IWE,VIWE,HEAVE,HEAVEL,HEAACC,PITCH,
     2 PITVEL,PITACC,VERVEL,VERACC,ZERO,INERT,RESTOR,EXCIT,CEP,
     2 HYDRO,LOAD,SF3(25,NOMEGA),SH3(25,NOMEGA)
      COMPLEX STEMP(25),CLENS(4,25),EXF,SAB33(25),CDUM,HYD,CSUM
      DIMENSION RAO(NOMEGA),PHS(NOMEGA),OMEGA(NOMEGA),OMEGAE(NOMEGA)
      DIMENSION SA33(25,NOMEGA),SB33(25,NOMEGA)
      REAL METER
      DATA METER /4HMETE/

      ZERO = (0.,0.)
      XP = XLDXPT(IP)
      KSTATN = LSTATN(IP) - 1
      NPS = NSTATN - KSTATN + 1
      V2 = V*V
      CON = 1000
      IF (PUNITS(1) .NE. METER) CON = 2240
      RHOG = RHO*GRAV
      DO 100 I=1,NU
      W = OMEGA(I)
      WN = W*W/GRAV
      TEST = .005*TPI/LPP
      ARGLI = - WN*COSMU
      IF (ABS(ARGLI) .LE. TEST) ARGLI = 0.
      WE = OMEGAE(I)
      WE2 = WE*WE
      IWE = XI*WE
      VIWE = V/IWE
      VWE2 = V/WE2
      V2WE2 = V2/WE2
      HEAVE = MOTV(2,I)
      HEAVEL = IWE*HEAVE
      HEAACC = IWE*HEAVEL
      PITCH = MOTV(3,I)
      PITVEL = IWE*PITCH
      PITACC = IWE*PITVEL
      VERVEL = HEAVEL - XP*PITVEL
      VERACC = HEAACC - XP*PITACC

C     INERTIA TERM
      INERT = ZERO
      N1 = KSTATN + 1
      DO 10 K=N1,NSTATN
      STEMP(K) = SMASS(K)*(HEAACC - X(K)*PITACC)
      IF (IM .EQ. 13) STEMP(K) = - (X(K)-XP)*STEMP(K)
      INERT = INERT + STEMP(K)
   10 CONTINUE

C     RESTORING TERM
      DO 20 K=KSTATN,NSTATN
      NPT = NOFSET(K)
      SBEAM = 2*Y(NP,,K)
      STEMP(K) = SBEAM*(HEAVE - X(K)*PITCH)
      IF (IM .EQ. 11) STEMP(K) = - STEMP(K)
      IF (IM .EQ. 13) STEMP(K) = (X(K)-XP)*STEMP(K)
   20 CONTINUE
      CALL CPFIT (X(KSTATN),STEMP(KSTATN),ELENS,NPS)
      CALL CPINTG (XP,X(NSTATN),X(KSTATN),NPS,ELENS,0.,NE,RESTOR)
      RESTOR = RHOG*RESTOR
```

```
C     EXCITING TERM
        DO 30 K=KSTATN,NSTATN
        STEMP(K) = SF3(K,I) + SH3(K,I)
        IF (IN .EQ. 13) STEMP(K) = - ((X(K)-XP)*STEMP(K) +
     2 VIWE*SH3(K,I))
   30   CONTINUE
        CALL CPFIT (X(KSTATN),STEMP(KSTATN),ELEMS,NPS)
        CALL CPINTG (XP,X(NSTATN),X(KSTATN),NPS,ELEMS,ARGLI,EXCIT)
        IF (.NOT. IN.EQ.11) GO TO 35
        CALL CPFIT (X(KSTATN),SH3(KSTATN,I),ELEMS,NPS)
        CALL CPLVAL (X(KSTATN),NPS,ELEMS,XP,EXF,CDUM,IELM)
        CEP = CEXP(II*XP*ARGLI)
        EXCIT = EXCIT + VIWE*CEP*EXF
   35   EXCIT = RHO*EXCIT

C     HYDRODYNAMIC TERM
        DO 40 K=KSTATN,NSTATN
        A33 = SA33(K,I)
        B33 = SB33(K,I)
        SAB33(K) = A33 + II*B33
        IF (IN .EQ. 11) STEMP(K) = - (A33*(HEAACC-X(K)*PITACC) +
     2 B33*(HEAVEL-X(K)*PITVEL) - VWE2*B33*PITACC + V*A33*PITVEL)
        IF (IN .EQ. 13) STEMP(K) = (X(K)-XP)*(A33*(HEAACC-X(K)*PITACC)
     2 + B33*(HEAVEL-X(K)*PITVEL)) + (V*A33*VERVEL - VWE2*B33*VERACC
     2 - V2WE2*(A33*PITACC + B33*PITVEL))
   40   CONTINUE
        CALL CPFIT (X(KSTATN),STEMP(KSTATN),ELEMS,NPS)
        CALL CPINTG (XP,X(NSTATN),X(KSTATN),NPS,ELEMS,0.,HYDRO)
        IF (.NOT. IN.EQ.11) GO TO 45
        CALL CPFIT (X(KSTATN),SAB33(KSTATN),ELEMS,NPS)
        CALL CPLVAL (X(KSTATN),NPS,ELEMS,XP,HYD,CDUM,IELM)
        A33 = REAL(HYD)
        B33 = AIMAG(HYD)
        HYDRO = HYDRO - (V*A33*VERVEL - VWE2*B33*VERACC -
     2 V2WE2*(A33*PITACC + B33*PITVEL))
   45   CONTINUE

        CSUM = RESTOR + EXCIT + HYDRO
        LOAD = INERT - CSUM
        LOAD = LOAD/CON
        CALL RAOPHA (LOAD,RAO(I),PHS(I),RADDEG,IFHS)
  100   CONTINUE

        RETURN
        END
*DECK LRAOUT
        SUBROUTINE LRAOUT
*CA DATINP
*CA GEOM
*CA STATE
*CA PHYSCO
*CA ENVIOR
*CA IO
*CA LOADS
        COMPLEX MOTV(3,30),MOTL(3,30,8),HWV(3,30),HWL(3 30),H7(30),
     2 SF3(25,30),SH3(25,30)
        DIMENSION SA33(25,30),SB33(25,30),CONGAU(30),VSFRAO(30),
     2 VSFPHS(30),VBMRAO(30),VBMPHS(30)
        REAL METER
        DATA METER /4HMETE/

        IF (PUNITS(1) .EQ. METER) UNITS = 7HM-TONS
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      IF (PUNITS(1) .NE. METER) UNITS = 7HFT-TONS
      REWIND LCOFIL
      REWIND ORGFIL
      READ (ORGFIL) TITLE,NVK,NMU,NOMEGA,OMEGA,NRANG,RLANG,VRT,LAT,
     2 ADDRES,LPP,BEAM,DRAFT,DISPLM,GM,DELGM,KG,KROLL,LCB,GRAV,RHO,
     2 VKDES,VKINC,DBLWL
      WRITE (LRAFIL) TITLE,NOMEGA,OMEGA,NVK,NMU,LPP,BEAM,DRAFT,DISPLM,
     2 GM,DELGM,KG,KROLL,LCB,DBLWL,GRAV,NSTATN,STATN,NLOADS,SWGHT,SMASS,
     2 XLDSTN,XLDKPT,X
      DO 300 IV=1,NVK
      DO 200 IH=1,NMU
      READ (ORGFIL) VKNOTS,HEADNG,OMEGAE
      IF (VRT) READ (ORGFIL) MOTV
      IF (LAT) READ (ORGFIL) MOTL
      IF (ADDRES) READ (ORGFIL) HJV,HJL,H7
      HDNG = 180. - HEADNG
      COSMU = COS(MU(IH,IV))
      DO 10 IW=1,NOMEGA
      READ (LCOFIL) (SF3(I,IW),SH3(I,IW),SA33(I,IW),SB33(I,IW),
     2 I=1,NSTATN)
   10 CONTINUE
      DO 100 IP=1,NLOADS
      IM = 11
      CALL LRAO (IM,1,NOMEGA,MOTV,SF3,SH3,SA33,SB33,VFS(IV),COSMU,
     2 OMEGA,OMEGAE,IP,VSFRAO,VSFPHS,3,NOMEGA,1)
      IM = 13
      CALL LRAO (IM,1,NOMEGA,MOTV,SF3,SH3,SA33,SB33,VFS(IV),COSMU,
     2 OMEGA,OMEGAE,IP,VBMRAO,VBMPHS,3,NOMEGA,1)
      WRITE (IPRIN,1000) TITLE,XLDSTN(IP),VKNOTS,HDNG
 1000 FORMAT (*1*/28X,20A4///13X*LOAD RESPONSE AMPLITUDE OPERATORS*
     2 * (RAOS) AND PHASES*///60X*STATION*F5.1///55X*SHIP SPEED =*,
     2 F3.0* KNOTS*/53X*SHIP HEADING =*F5.0* DEGREES*)
      WRITE (IPRIN,1010) UNITS
 1010 FORMAT (//20X*V.SHEAR(V3)*9X*V.MOM.(V5)*/2X*OMEGA OMEGAE*4X,
     2 2(*AMPL.      PHASE*,4X)/4X*RPS*4X*RPS*4X* TONS*8X*DEG*4X,A7,
     2 5X*DEG*/)
      DO 20 IW=1,NOMEGA
      WRITE (IPRIN,1020) OMEGA(IW),OMEGAE(IW),VSFRAO(IW),VSFPHS(IW),
     2 VBMRAO(IW),VBMPHS(IW)
 1020 FORMAT (2F7.3,2(1PE12.4,0PF7.1))
   20 CONTINUE
      WRITE (IPRIN,1030)
 1030 FORMAT (//2X*NOTE:  HEADING CONVENTION: 0 DEG=HEAD, 90 DEG=*
     2 * STBD BEAM, 180 DEG= FOLLOWING SEAS.*)
      WRITE (LRAFIL) XLDSTN(IP),VKNOTS,HDNG,OMEGAE,VSFRAO,VSFPHS,
     2 VBMRAO,VBMPHS
  100 CONTINUE
  200 CONTINUE
  300 CONTINUE
      REWIND ORGFIL
      REWIND LRAFIL

      RETURN
      END
*DECK SETSEV
      SUBROUTINE SETSEV (NSVRSP,LSVRSP)
*CA RESPN
      DIMENSION LSVRSP(NSVRSP)

      DO 150 LR=1,NSVRSP
      DO 140 IR=1,NRESP
      IP = IPOINT(IR)
```

```
      IM = IMOTN(IR)
      IT = ITYPE(IR)
      GO TO (10,20,30,40,50,60,70,80,90,100,110,120,130),LR
10    IF (.NOT. (IP.EQ.0 .AND. IM.EQ.3 .AND. IT.EQ.1)) GO TO 140
C    HEAVE
      GO TO 150
20    IF (.NOT. (IP.EQ.0 .AND. IM.EQ.5 .AND. IT.EQ.1)) GO TO 140
C    PITCH
      GO TO 150
30    IF (.NOT. (IP.EQ.0 .AND. IM.EQ.2 .AND. IT.EQ.1)) GO TO 140
C    SWAY
      GO TO 150
40    IF (.NOT. (IP.EQ.0 .AND. IM.EQ.4 .AND. IT.EQ.1))  GO TO 140
C    ROLL
      GO TO 150
50    IF (.NOT. (IP.EQ.0 .AND. IM.EQ.6 .AND. IT.EQ.1))  GO TO 140
C    YAW
      GO TO 150
60    IF (.NOT. (IP.EQ.1 .AND. IM.EQ.3 .AND. IT.EQ.3))  GO TO 140
C    VERTICAL ACCELERATION AT POINT 1 (P1)
      GO TO 150
70    IF (.NOT. (IP.EQ.1 .AND. IM.EQ.2 .AND. IT.EQ.3)) GO TO 140
C    LATERAL ACCELERATION AT POINT 1 (P1)
      GO TO 150
80    IF (.NOT. (IP.EQ.2 .AND. IM.EQ.3 .AND. IT.EQ.3))  GO TO 140
C    VERTICAL ACCELERATION AT POINT 2 (P2)
      GO TO 150
90    IF (.NOT. (IP.EQ.2 .AND. IM.EQ.2 .AND. IT.EQ.3)) GO TO 140
C    LATERAL ACCELERATION AT POINT 2 (P2)
      GO TO 150
100   IF (.NOT. (IP.EQ.3 .AND. IM.EQ.3 .AND. IT.EQ.3)) GO TO 140
C    VERTICAL ACCELERATION AT POINT 3 (P3)
      GO TO 150
110   IF (.NOT. (IP.EQ.3 .AND. IM.EQ.2 .AND. IT.EQ.3))  GO TO 140
C    LATERAL ACCELERATION AT POINT 3 (P3)
      GO TO 150
120   IF (.NOT. (IP.EQ.4 .AND. IM.EQ.3 .AND. IT.EQ.3)) GO TO 140
C    VERTICAL ACCELERATION AT POINT 4 (P4)
      GO TO 150
130   IF (.NOT. (IP.EQ.4 .AND. IM.EQ.2 .AND. IT.EQ.3)) GO TO 140
C    LATERAL ACCELERATION AT POINT 4 (P4)
      GO TO 150
140   CONTINUE
150   LSVRSP(LR) = IR
160   CONTINUE

      RETURN
      END
*DECK SEVMOT
      SUBROUTINE SEVMOT (NSVRSP,LSVRSP,RSPNME,HDNG,IMODL)
*CA DATINP
*CA INDEX
*CA GEOM
*CA PHYSCO
*CA IO
*CA ENVIOR
*CA SEVERE

      DIMENSION RSV(13,13),TOE(13,13),TEMV(13),TEMH(13),TEMR(13),
     2 TEMT(13),LSVRSP(13),RSPNME(2,13),HDNG(24),IMODL(4)
      INTEGER TEMT
      REAL METER
```

```
      DATA METER /4HMETE/
      NHEAD = 24
      N1 = NHEAD + 1
      NDATA = 2 + N1*NVK*2
      DO 500 IC=1,2
      DO 400 IS=1,NSIGWH
      LT = IMODL(IS)
      DO 300 IR=1,NSVRSP
      DO 200 JR=1,NSVRSP
      CALL FETCH (IC,JR,IS,RSVTOE,SVIDX,RSINDX,SWINDX,NDATA,LSVIDX,
    2 NRSIND,NSWIND,SEVFIL)
      IF (IR .GT. 1) GO TO 10
      RV(JR) = RSVTOE(1) + .001
      RH(JR) = RSVTOE(2)+ .001
   10 IF (JR .GT. 1) GO TO 20
      IV = RV(IR)
      IH = RH(IR)
   20 IE = 3 + (IH-1)*2 + (IV-1)*NHEAD*2
      RSV(JR,IR) = RSVTOE(IE)
      TOE(JR,IR) = RSVTOE(IE+1)
  200 CONTINUE
  300 CONTINUE
      WRITE (IPRIN,1000) TITLE
 1000 FORMAT (*1*/28X,20A4///48X*S E V E R E   M O T I O N   T A B L *
    2 *E*)
      IF (IC .EQ. 1) WRITE (IPRIN,1010)
      IF (IC .EQ. 2) WRITE (IPRIN,1020)
 1010 FORMAT (//60X,11HLONGCRESTED)
 1020 FORMAT (//60X,12HSHORTCRESTED)
      IF (PUNITS(1) .NE. METER) WRITE (IPRIN,1030) SIGWH(IS)
      IF (PUNITS(1) .EQ. METER) WRITE (IPRIN,1040) SIGWH(IS)
 1030 FORMAT (/42X*SEA STATE:  SIGNIFICANT WAVE HEIGHT =*F6.2* FEET  *)
 1040 FORMAT (/42X*SEA STATE:  SIGNIFICANT WAVE HEIGHT =*F6.2* METERS*)
      WRITE (IPRIN,1050) TMODAL(LT)
      IF (NSVRSP .EQ. 5) GO TO 60
      NP = NSVRSP - 5
      NP = NP / 2
      WRITE (IPRIN,1025)
 1025 FORMAT (//54X*POINT LOCATIONS:*)
      DO 50 IP=1,NP
      WRITE (IPRIN,1026) IP,(PTNAME(I,IP),I=1,8),XPTLOC(IP),
    2 YPTLOC(IP),ZPTLOC(IP)
 1026 FORMAT (22X*P*I1*-  *8A4,2X,*XFP =*F7.2,2X*YCL =*F7.2,2X,
    2 *ZBL =*F7.2)
   50 CONTINUE
   60 CONTINUE
 1050 FORMAT (54X*MODAL WAVE PERIOD =*F4.0* SECONDS*)
      WRITE (IPRIN,1055) (STATNM(I),I=1,3)
 1055 FORMAT (//40X,3A4,* VALUE / ENCOUNTERED MODAL PERIOD (TOE)*)
      WRITE (IPRIN,1060) ((RSPNME(I,IR),I=1,2),IR=1,NSVRSP)
 1060 FORMAT (//48X*MAXIMUM RESPONSES AND CONDITIONS*/1X,130(1H-)//
    2 * RESPONSE      *,13(4X,A4,A1))
      DO 310 IR=1,NSVRSP
      IV = RV(IR)
      IH = RH(IR)
      TEMV(IR) = VK(IV)
      TEMH(IR) = HDNG(IH)
      TEMR(IR) = RSV(IR,IR)
      IF (IR .GT. 5) TEMR(IR) = TEMR(IR) * 100
      TEMT(IR) = TOE(IR,IR)
  310 CONTINUE
      WRITE (IPRIN,1070) (TEMR(IR),TEMT(IR),IR=1,NSVRSP)
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```
1070  FORMAT (/* (MAX.RSV)/TOE*,13(1X,F6.2,1H/,I2))
      WRITE (IPRIN,1080) (TEMV(IR),IR=1,NSVRSP)
1080  FORMAT (* AT SPEED (KNOTS)*,F6.1,12F9.1)
      WRITE (IPRIN,1090) (TEMH(IR),IR=1,NSVRSP)
1090  FORMAT (* AT HEADING (DEG)*,F6.0,12F9.0)
      WRITE (IPRIN,1100) ((RSPNME(I,JR),I=1,2),JR=1,NSVRSP)
1100  FORMAT (//54X*ASSOCIATED RESPONSES*/1X,130(1H-)//
    2 * MAX.   SPEED /*/* RESPN. HEADING*,3X,A4,A1,12(4X,A4,A1))
      WRITE (IPRIN,1110)
1110  FORMAT (1X)
      DO 330 IR=1,NSVRSP
      IV = RV(IR)
      IH = RH(IR)
      MV = VK(IV) + .001
      MH = HDNG(IH) + .001
      IF (IR.EQ.6 .OR. IR.EQ.8 .OR. IR.EQ.10 .OR. IR.EQ.12)
    2 WRITE (IPRIN,1110)
      DO 320 JR=1,NSVRSP
      TEMR(JR) = RSV(JR,IR)
      IF (JR .GT. 5) TEMR(JR) = TEMR(JR) * 100
      TEMT(JR) = TOS(JR,IR)
 320  CONTINUE
      WRITE (IPRIN,1120) (RSPNME(I,IR),I=1,2),MV,MH,(TEMR(JR),TEMT(JR),
    2 JR=1,NSVRSP)
1120 FORMAT (1X,A4,A1,2X,I2,1H/,I3,13(F6.2,1H/,I2))
 330  CONTINUE
      WRITE (IPRIN,1130)
1130  FORMAT (//2X*NOTES: 1) RESPONSES ARE IN PHYSICAL UNITS:*/
    2 22X,*HEAVE AND SWAY ARE IN WAVE HEIGHT UNITS;   PITCH, *
    2 *ROLL, AND YAW ARE IN DEGREES;*/22X,*AND THE POINT VERTICAL *
    2 *AND LATERAL ACCELERATIONS ARE IN UNITS OF  G-S *,1H*,* 100.*)
      WRITE (IPRIN,1140)
1140  FORMAT (9X*2) POINT LOCATIONS:    XFP IS IN STATION NUMBERS;  *
    2 *YCL AND ZBL ARE IN WAVE HEIGHT UNITS.*)
      WRITE (IPRIN,1150)
1150  FORMAT (9X*3) HEADING CONVENTION: 0 DEG=HEAD, 90 DEG=STBD BEAM,*
    2 * 180 DEG=FOLLOWING SEAS.*)
 400  CONTINUE
 500  CONTINUE

      RETURN
      END
```

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CARDEROCK DIVISION

CARDEROCK DIVISION HEADQUARTERS
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ERRATA

IN REPLY REFER TO:
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Alexandria, VA 22304-6145

Gentlemen:

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Sincerely,

W. B. Morgan

W. B. MORGAN
Head, Hydromechanics Directorate

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